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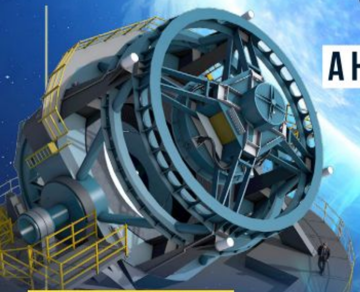

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Issue 117

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Did you know that there are some stars in the universe that are missing? In this issue of **All About Space**, we discover that an international team of astronomers is currently searching for them, but are they gone for good?

It turns out that we might have chanced upon a cosmic object that has been unknown up until now - and with quite mind-boggling implications: could this be the smoking gun for the Search for Extraterrestrial Intelligence (SETI)? Turn to page 14 to find out.

Also this month, we uncover the scrapped plans that would have seen humanity reaching for the Moon much sooner than the Apollo astronauts; give you tips and tricks on how to spot fake astrophotography images - for those who have ever been caught out on social media! - reveal more about the upcoming Vera C. Rubin Observatory, which will provide the best views of the universe from Earth; why the Sun has gone to sleep and much more. We're also giving away three free digital eBooks for you to get stuck into.

All our regular features are also here: from your questions being answered by our expert panel in Ask Space to our night-sky guides, reviews, future tech and heroes of space.

Enjoy the issue - I'll see you again on 17 June for more news from around the cosmos.

GEMMA LAVENDER

EDITOR-IN-CHIEF

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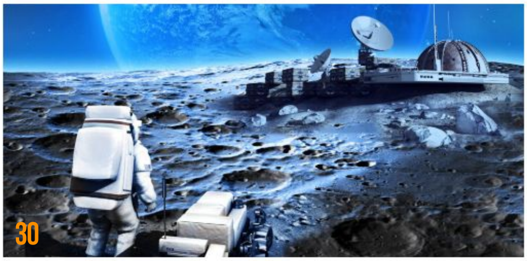

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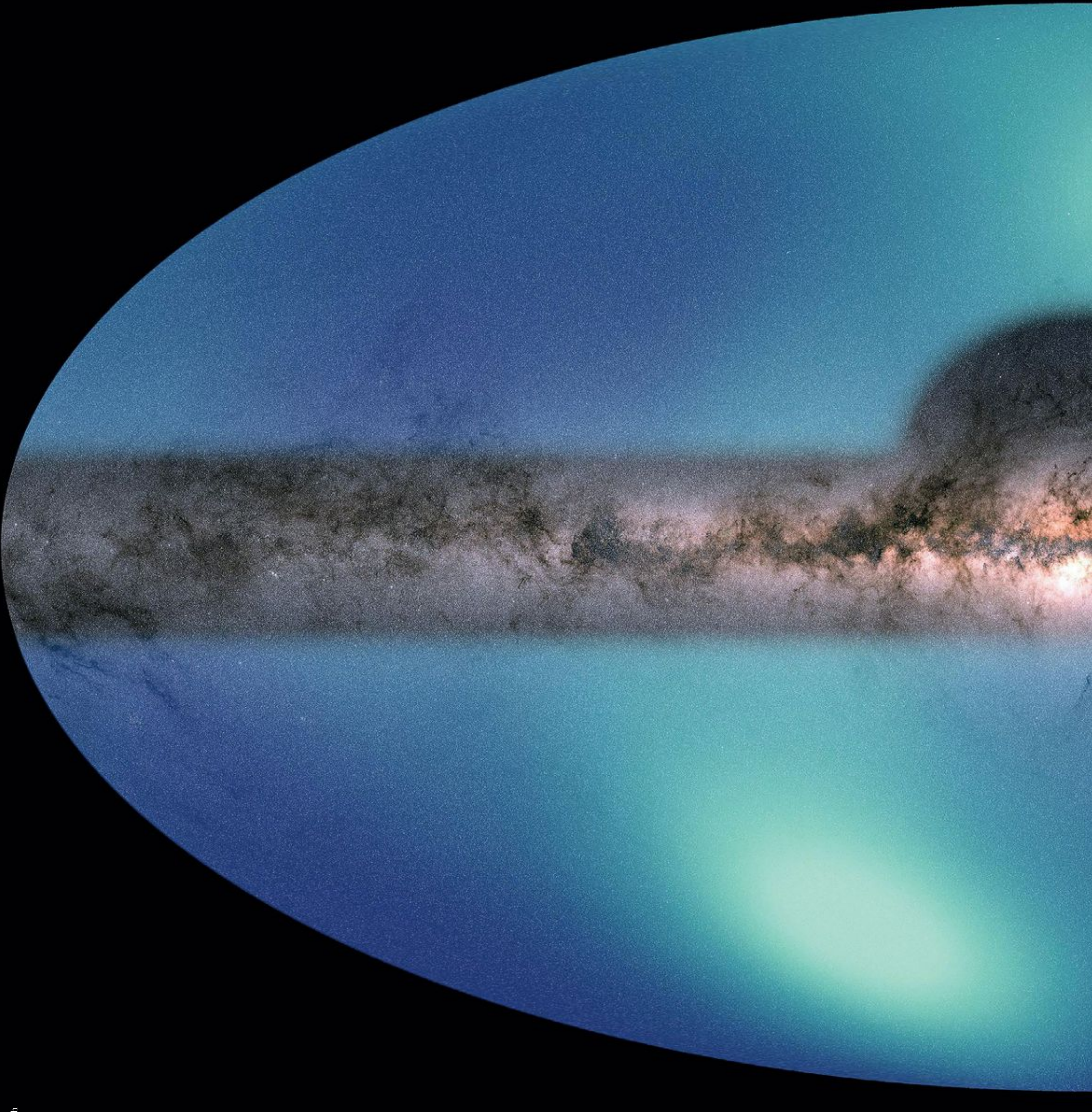

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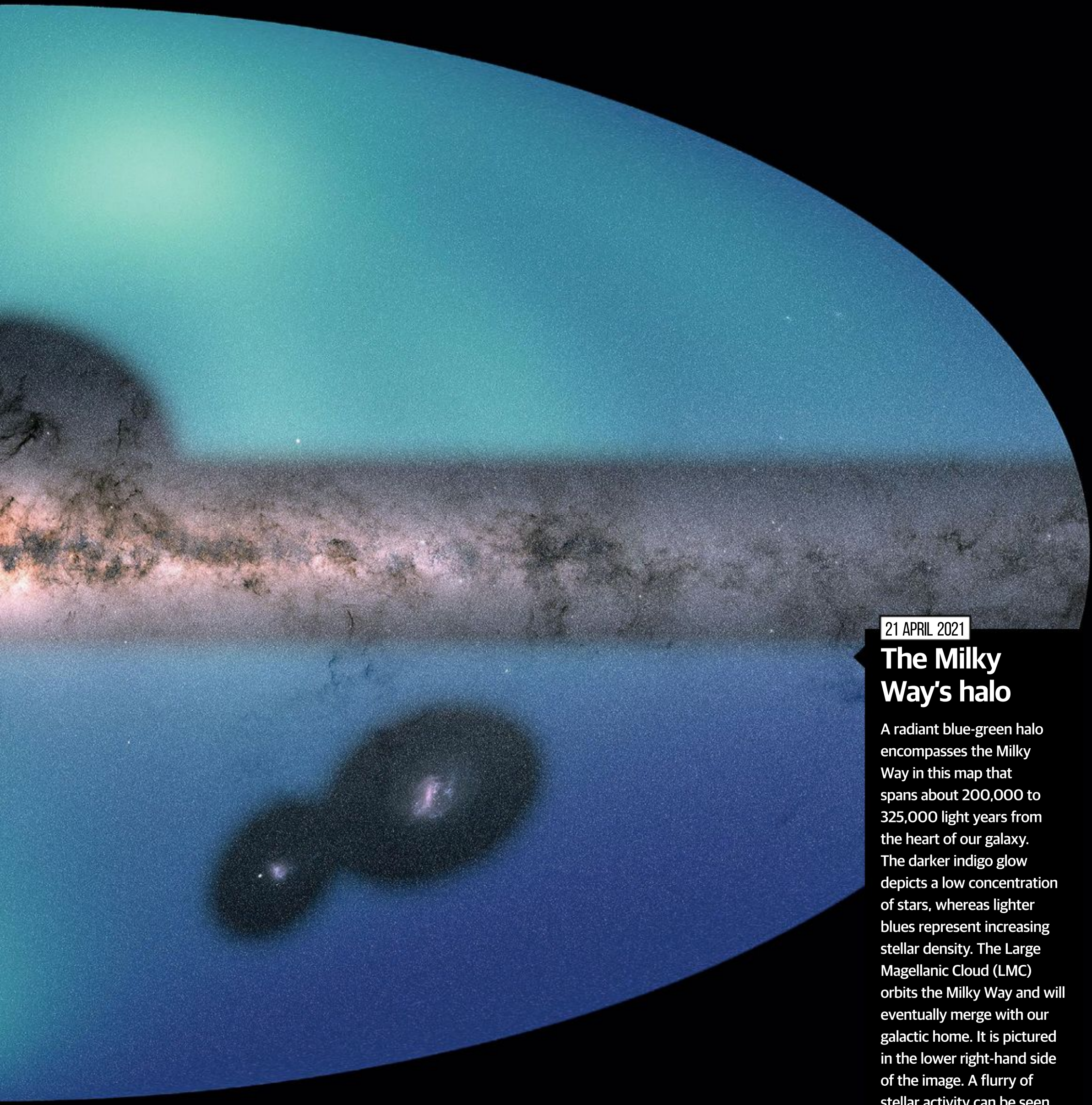


21 APRIL 2021

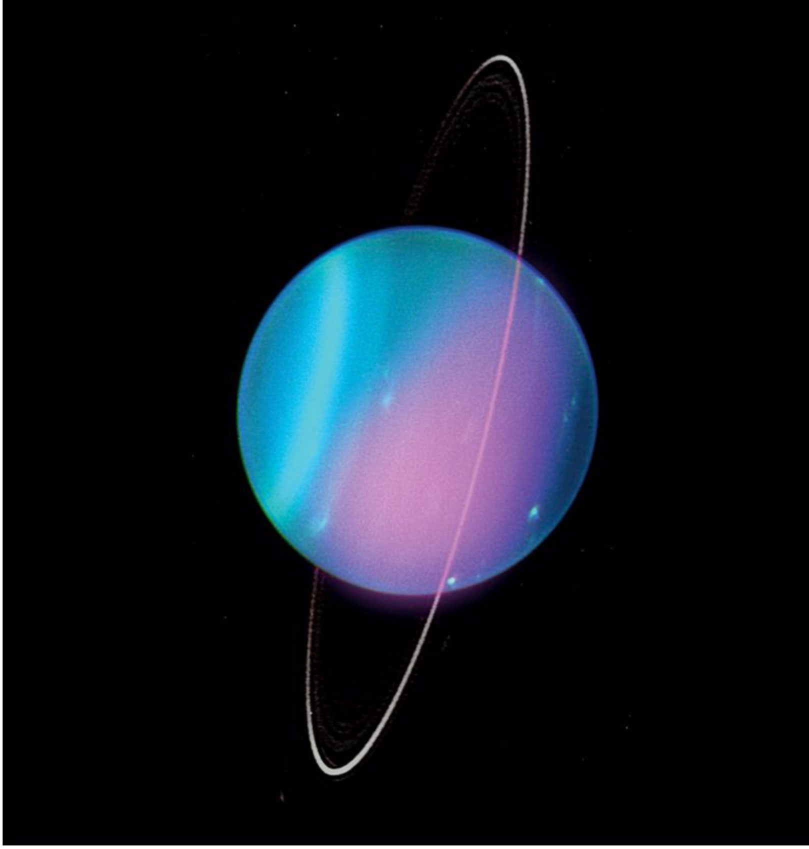
The Milky Way's halo

A radiant blue-green halo encompasses the Milky Way in this map that spans about 200,000 to 325,000 light years from the heart of our galaxy. The darker indigo glow depicts a low concentration of stars, whereas lighter blues represent increasing stellar density. The Large Magellanic Cloud (LMC) orbits the Milky Way and will eventually merge with our galactic home. It is pictured in the lower right-hand side of the image. A flurry of stellar activity can be seen as a sweeping vivid glow in the lower half of the image, caused by the LMC cruising through the galactic halo.

31 MARCH 2021

X-rays burst from Uranus

The hazy blue of Uranus is besmirched by a pink glow: X-ray emissions captured for the first time by NASA's Chandra X-ray Observatory. The discovery of X-ray emissions from Uranus relied on Chandra observations, though the exact cause of the X-ray emissions remains unknown. One idea is that due to the enormous size of Uranus, the planet could be scattering X-rays given off by the distant Sun. The other suggestion is that the rings surrounding the planet are generating their own radiation through an unidentified process.



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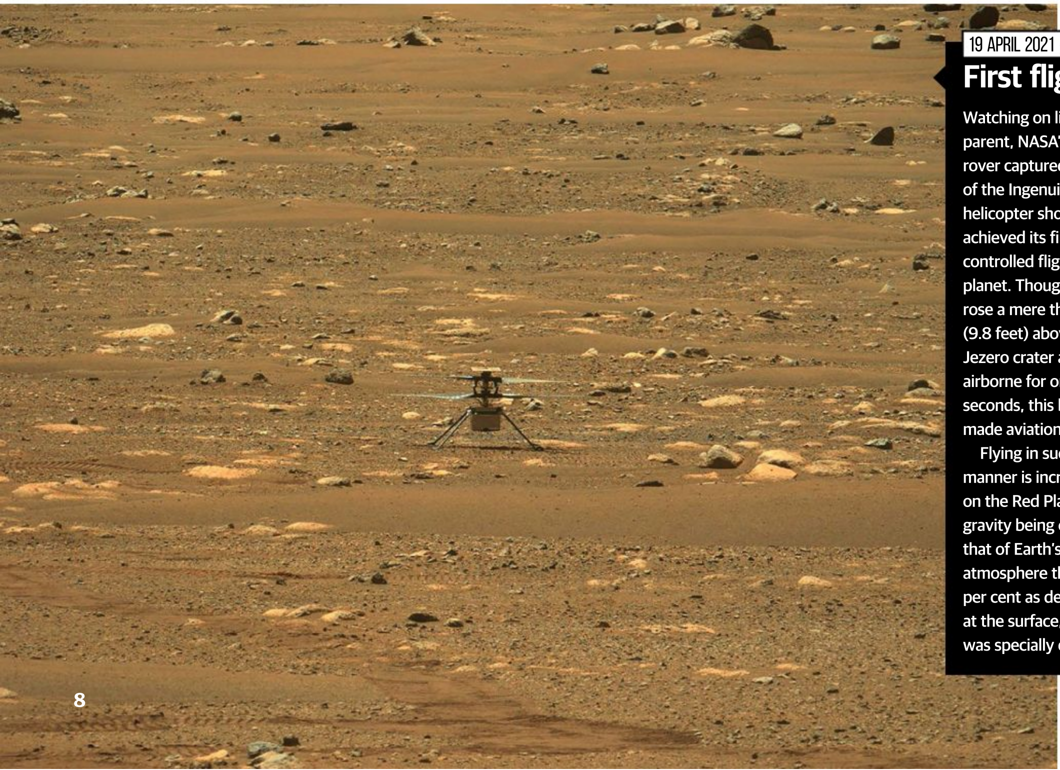

19 APRIL 2021

First flight

Watching on like a proud parent, NASA's Perseverance rover captured this image of the Ingenuity Mars helicopter shortly after it achieved its first powered controlled flight on another planet. Though Ingenuity rose a mere three metres (9.8 feet) above the floor of Jezero crater and remained airborne for only 39 seconds, this brief flight has made aviation history.

Flying in such a controlled manner is incredibly difficult on the Red Planet due to gravity being one-third that of Earth's and an atmosphere that is only one per cent as dense as Earth's at the surface, but Ingenuity was specially designed for it.

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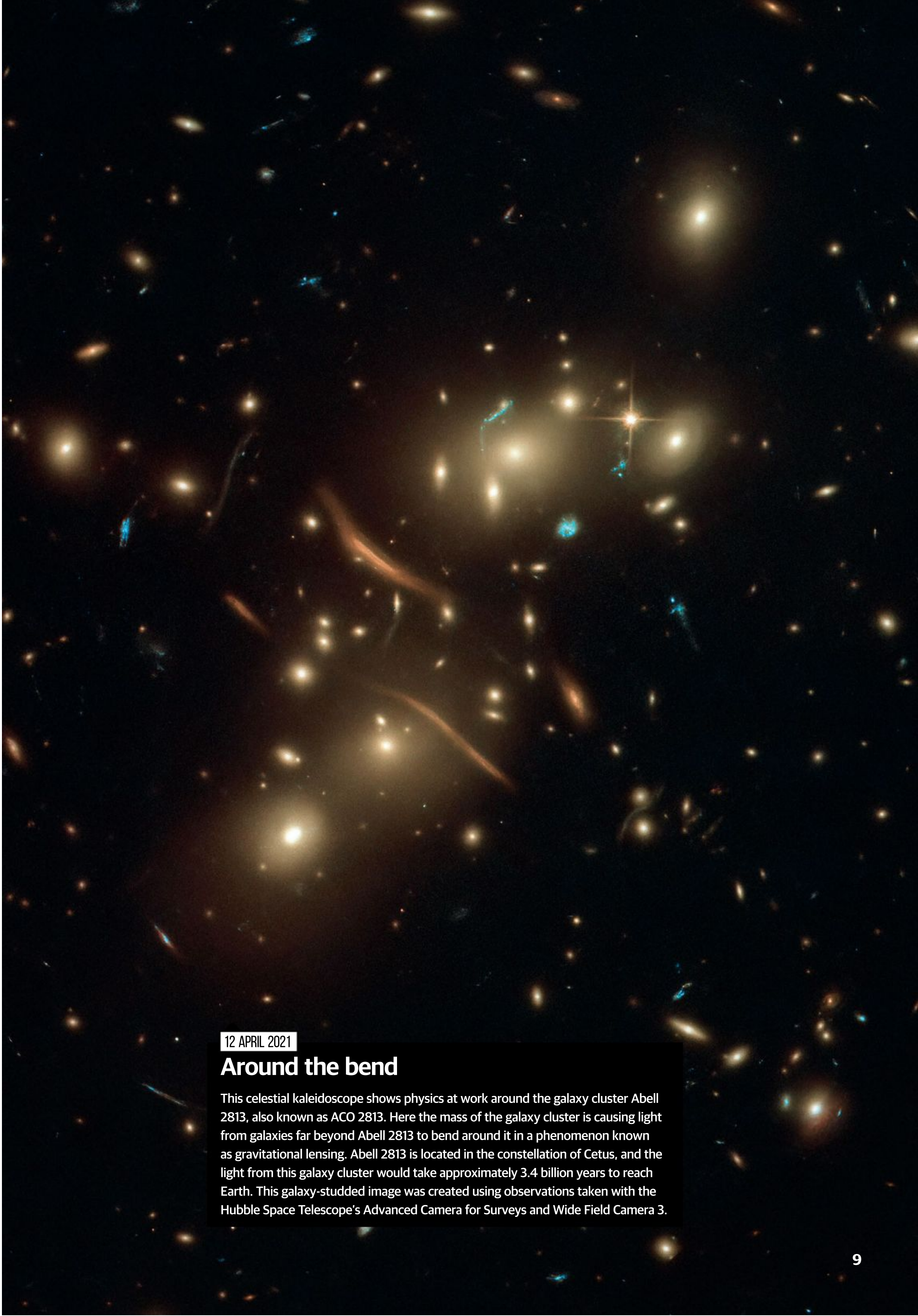

12 APRIL 2021

Around the bend

This celestial kaleidoscope shows physics at work around the galaxy cluster Abell 2813, also known as ACO 2813. Here the mass of the galaxy cluster is causing light from galaxies far beyond Abell 2813 to bend around it in a phenomenon known as gravitational lensing. Abell 2813 is located in the constellation of Cetus, and the light from this galaxy cluster would take approximately 3.4 billion years to reach Earth. This galaxy-studded image was created using observations taken with the Hubble Space Telescope's Advanced Camera for Surveys and Wide Field Camera 3.

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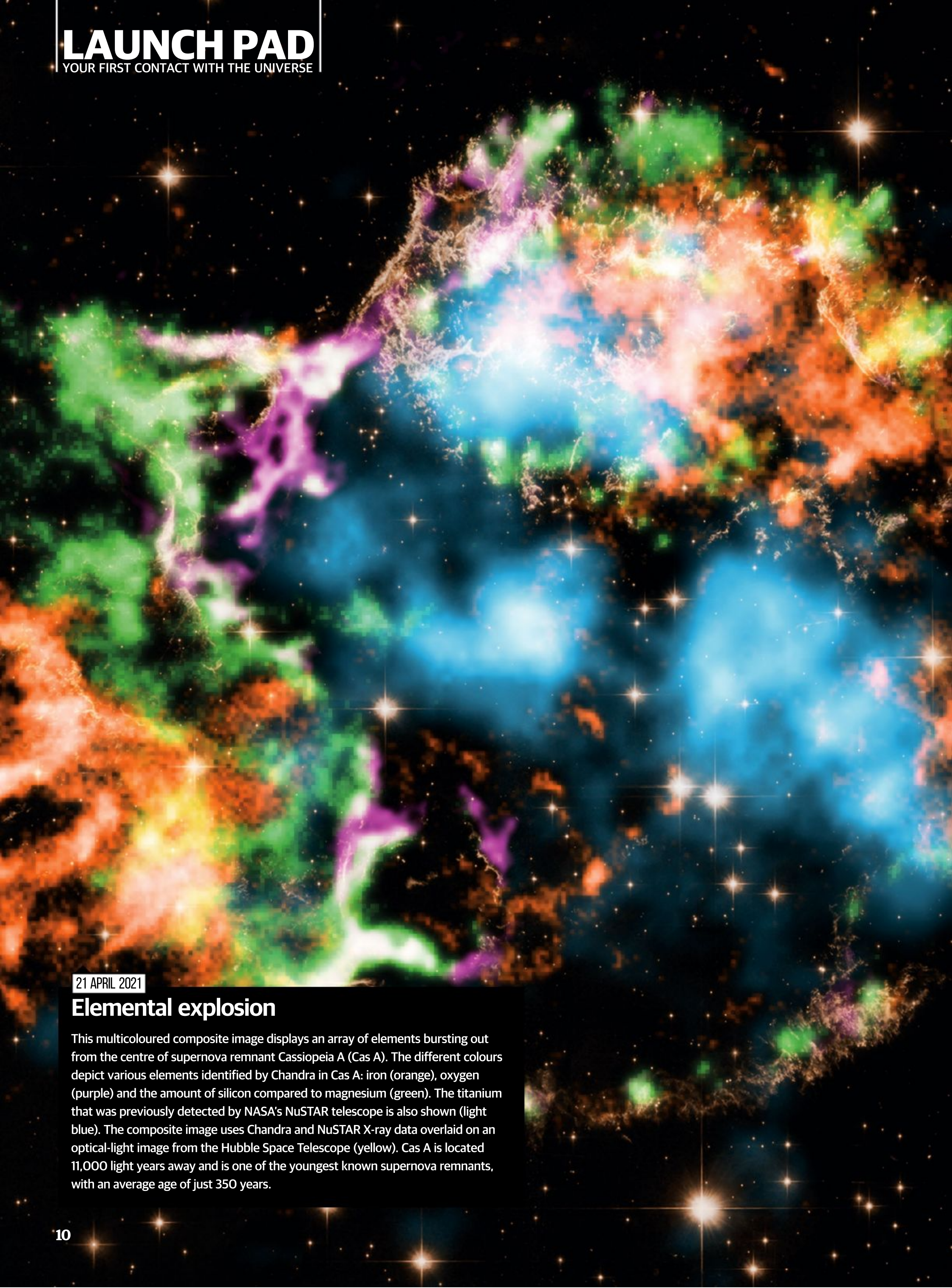
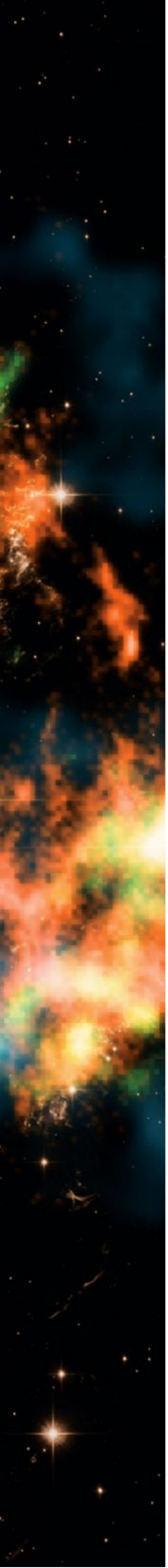


21 APRIL 2021

Elemental explosion

This multicoloured composite image displays an array of elements bursting out from the centre of supernova remnant Cassiopeia A (Cas A). The different colours depict various elements identified by Chandra in Cas A: iron (orange), oxygen (purple) and the amount of silicon compared to magnesium (green). The titanium that was previously detected by NASA's NuSTAR telescope is also shown (light blue). The composite image uses Chandra and NuSTAR X-ray data overlaid on an optical-light image from the Hubble Space Telescope (yellow). Cas A is located 11,000 light years away and is one of the youngest known supernova remnants, with an average age of just 350 years.



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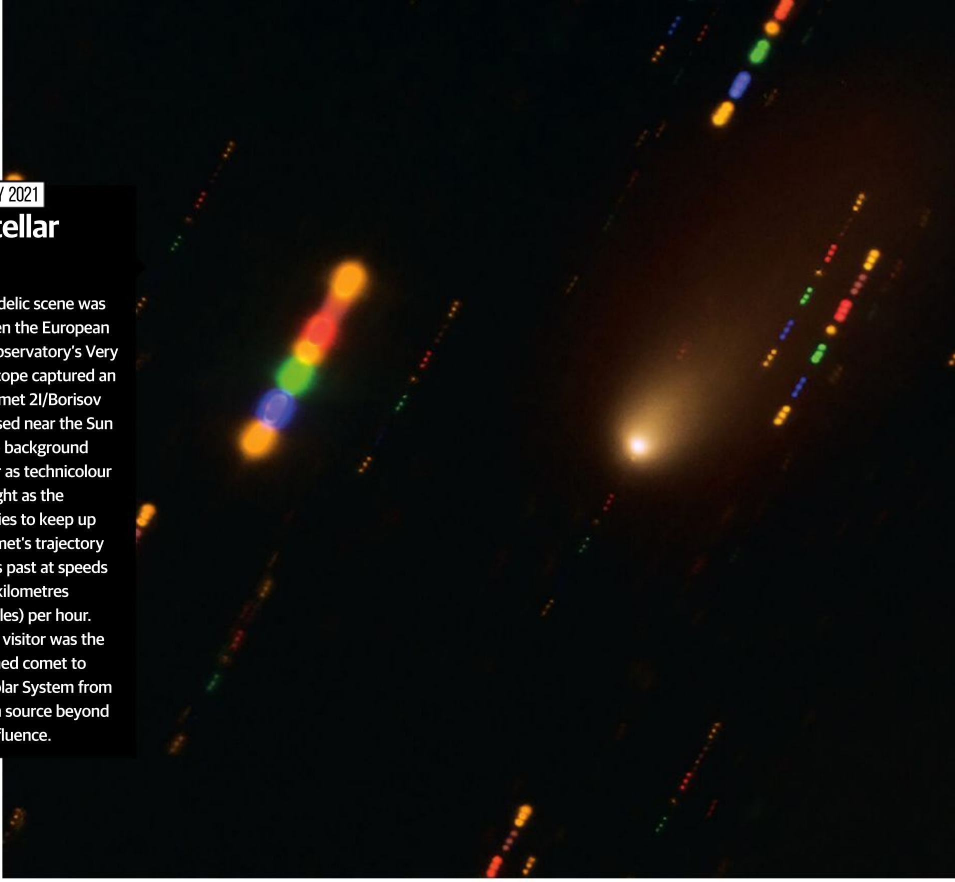

25 FEBRUARY 2021

Interstellar disco

This psychedelic scene was created when the European Southern Observatory's Very Large Telescope captured an image of Comet 2I/Borisov when it passed near the Sun in 2019. The background stars appear as technicolour streaks of light as the telescope tries to keep up with the comet's trajectory as it whizzes past at speeds of 177,000 kilometres (110,000 miles) per hour. This speedy visitor was the first confirmed comet to enter our Solar System from an unknown source beyond our Sun's influence.

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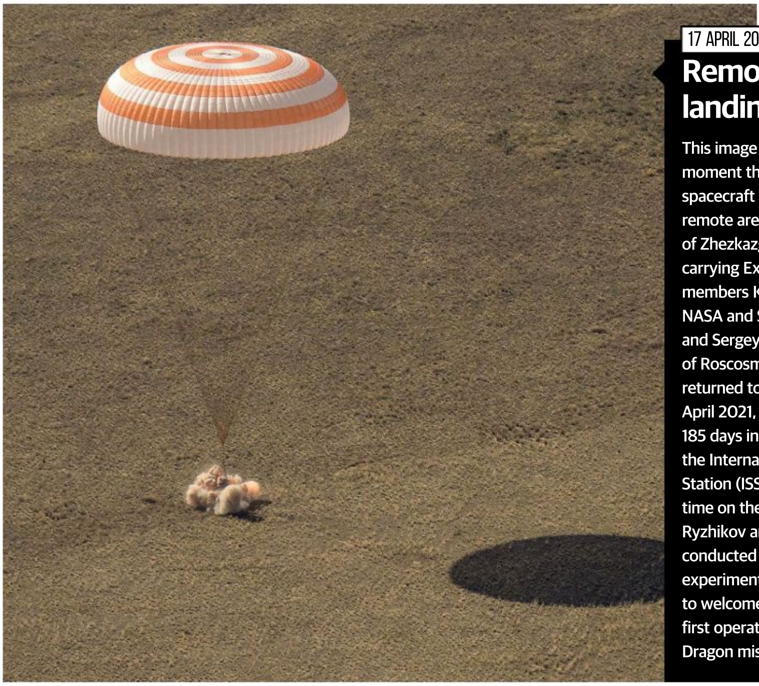


17 APRIL 2021

Remote landing

This image captures the moment the Soyuz MS-17 spacecraft landed in a remote area close to the city of Zhezkazgan, Kazakhstan, carrying Expedition 64 crew members Kate Rubins of NASA and Sergey Ryzhikov and Sergey Kud-Sverchkov of Roscosmos. The trio returned to Earth on 17 April 2021, having spent 185 days in space on board the International Space Station (ISS). During their time on the ISS, Rubins, Ryzhikov and Kud-Sverchkov conducted hundreds of experiments and were there to welcome aboard SpaceX's first operational Crew Dragon mission.

©NASA

NASA'S PERSEVERANCE MAKES OXYGEN ON MARS FOR THE FIRST TIME

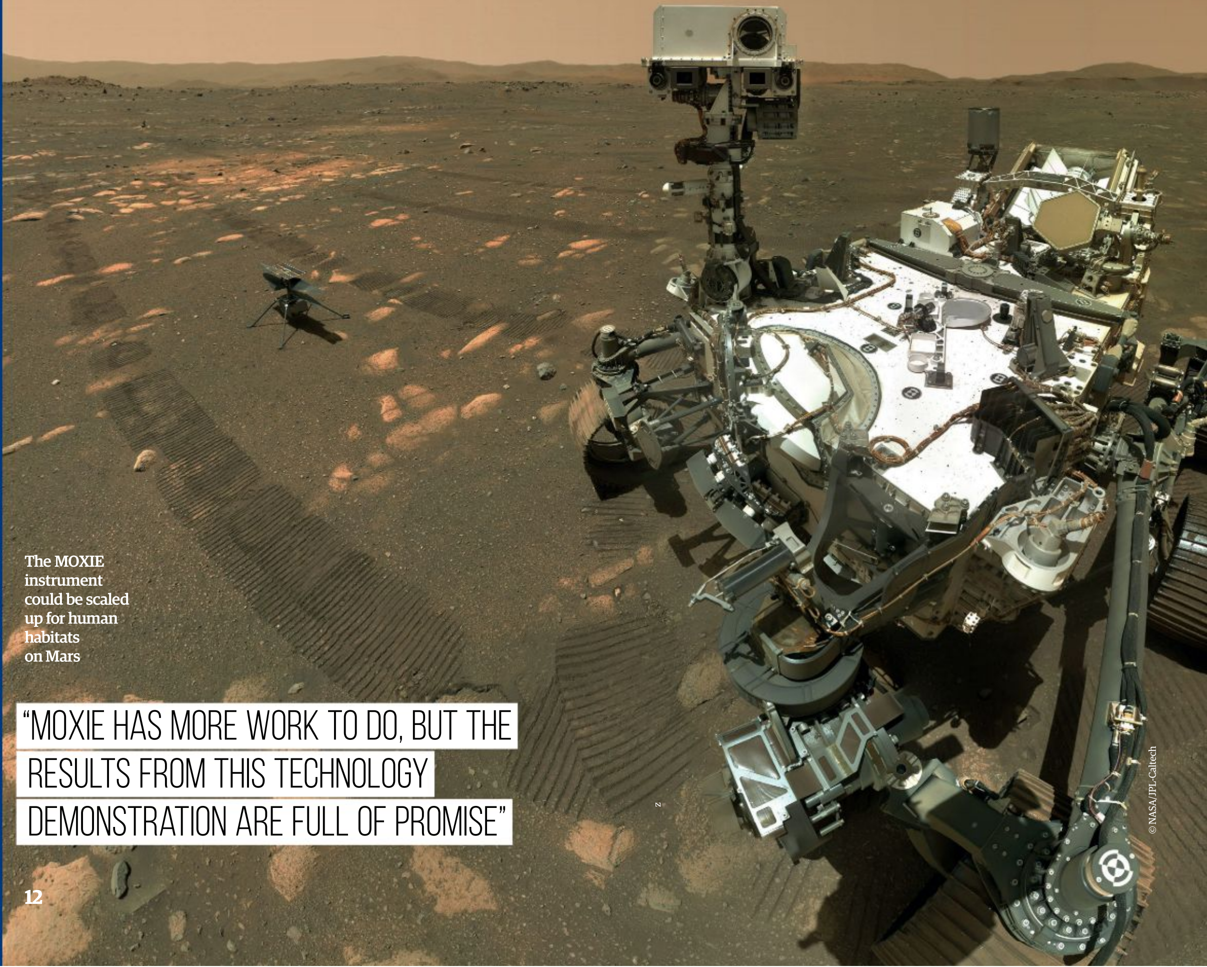
Words by Mike Wall

NASA's Perseverance rover just notched another first on Mars, one that may help pave the way for astronauts to explore the Red Planet someday. The rover successfully used its MOXIE (Mars Oxygen In-Situ Resource Utilization Experiment) instrument to generate oxygen from the thin, carbon dioxide-dominated Martian atmosphere for the first time, demonstrating technology that could both help astronauts breathe and help propel the rockets that get them back home to Earth.

The MOXIE milestone occurred on 20 April, just one day after Perseverance watched over another epic Martian first: the first Mars flight of NASA's Ingenuity helicopter, which rode to the Red Planet on the rover's belly. "This is a critical first step at converting carbon dioxide to oxygen on Mars," said Jim Reuter, acting associate administrator of NASA's Space Technology Mission Directorate. "MOXIE has more work to do, but the results from this technology demonstration are full of promise as we move towards our goal of one day seeing humans on Mars."

The toaster-sized MOXIE produces oxygen from carbon dioxide, expelling carbon monoxide as a waste product. The process occurs at temperatures around 800 degrees Celsius (1,472 degrees Fahrenheit), so MOXIE is made of heat-tolerant materials and features a thin gold coating to keep potentially damaging heat from radiating outward into Perseverance's body. The MOXIE team warmed the instrument up for two hours, then had it crank out oxygen for an hour. MOXIE produced 5.4 grams of oxygen during that span, about enough to keep an astronaut breathing easily for ten minutes. That first effort didn't max MOXIE out; it can generate about ten grams of oxygen per hour. The instrument may reach such levels eventually, as the team plans to conduct about nine more runs over the course of one Mars year.

These trials will be grouped into three phases. The first phase is checking and characterising the instrument, and the second will assess MOXIE's performance in varying atmospheric conditions. During the third and final phase, "we'll push the envelope," said MOXIE principal investigator Michael Hecht. Pushing the envelope will likely involve testing new operating modes or adding "new wrinkles, such as a run where we compare operations at three or more different temperatures".



The MOXIE instrument could be scaled up for human habitats on Mars

"MOXIE HAS MORE WORK TO DO, BUT THE RESULTS FROM THIS TECHNOLOGY DEMONSTRATION ARE FULL OF PROMISE"

© NASA/JPL-Caltech

©Ohio State illustration by Lauren Fanfer

Above: If it is indeed a black hole, it's a very small one

TINY NEWFOUND 'UNICORN' IS CLOSEST KNOWN BLACK HOLE TO EARTH

Words by Mike Wall

Astronomers have apparently found the closest known black hole to Earth, a weirdly tiny object dubbed 'the Unicorn' that lurks just 1,500 light years from us. The nickname has a double meaning: not only does the black hole candidate reside in the constellation Monoceros (the Unicorn), its incredibly low mass - about three times that of the Sun - makes it nearly one of a kind. The Unicorn has a companion - a bloated red giant star that's nearing the end of its life. That companion has been observed by a variety of instruments over the years, including the All Sky Automated Survey and NASA's Transiting Exoplanet Survey Satellite.

Scientists analysed the data from these instruments and noticed something interesting. The red giant's light shifts in intensity periodically, suggesting that another object is tugging on the star and changing its shape. They determined that the object doing the tugging is likely a black hole - one harbouring a mere three solar masses - based on details of the star's velocity and the light distortion. For perspective, the supermassive black hole at the heart of our Milky Way galaxy packs about 4.3 million solar masses.

"Just as the Moon's gravity distorts Earth's oceans, causing the seas to bulge towards and away from the Moon, so does the black hole distort the star into a rugby-ball shape, with one axis longer than the other," said Todd Thompson, chair of Ohio State's astronomy department. "The simplest explanation is that it's a black hole - and the simplest explanation is the most likely one."

SPACEX COULD LAND ASTRONAUTS ON THE MOON IN 2024, SAYS ELON MUSK

Words by Mike Wall

Elon Musk doesn't think NASA's 2024 Moon landing goal is out of reach. The space agency is working to get people back to the Moon via its Artemis program, which aims to establish a long-term, sustainable human presence on and around Earth's nearest neighbour by the end of the 2020s. In 2019, the Trump administration directed NASA to make the first crewed Artemis landing by 2024. Experts have generally viewed that target as overly ambitious, and it's unclear whether the timeline will hold under President Joe Biden. But Musk, SpaceX's founder and CEO, thinks it is indeed achievable with the company's Starship deep-space transportation system, which NASA recently selected as Artemis' crewed Moon lander.

"I think it will happen. I think 2024 seems likely," said Musk in a news conference "We're gonna aim for sooner than that," he added. Indeed, Musk said he thinks Starship - a giant, reusable rocket-spaceship combo - could be flying people regularly by 2023.

Below: Starship is now part of the Artemis program

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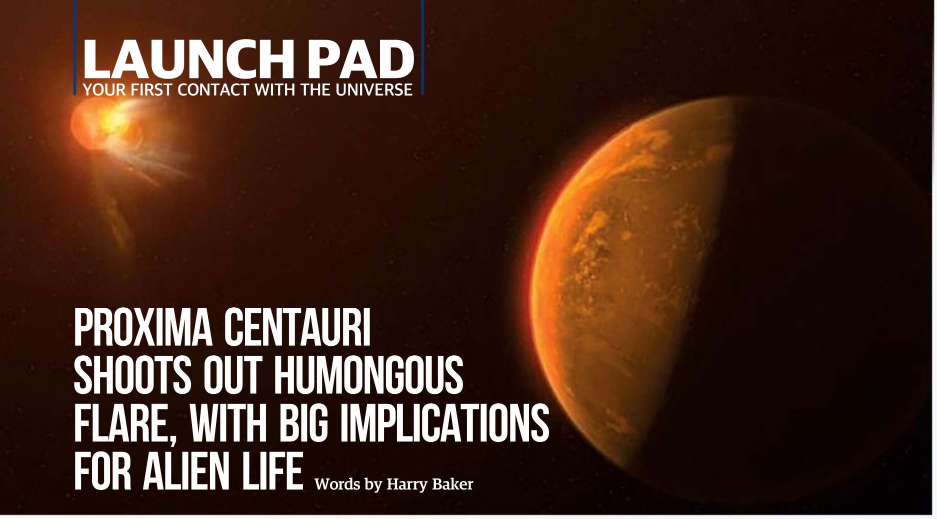


PROXIMA CENTAURI SHOOTS OUT HUMONGOUS FLARE, WITH BIG IMPLICATIONS FOR ALIEN LIFE

Words by Harry Baker

Scientists have spotted one of the largest stellar flares ever recorded in our galaxy. The jets of plasma shot outward from the Sun's nearest neighbour, the red dwarf star Proxima Centauri. The flare, which was around 100 times more powerful than any experienced in our Solar System, could change the way scientists think about stellar radiation and alien life.

Proxima Centauri is a red dwarf star located approximately 4.25 light years from Earth. Its mass is one-eighth of the Sun's, and it is orbited by two known exoplanets. One of these planets, Proxima Centauri b, is considered to be Earth-like and lies within the star's habitable zone - the distance from a star that could support the development of life. Stellar flares are the result of a star's strong magnetic fields. These fields - which are created by large amounts of electrically charged gas - can get twisted together and suddenly snap back into place to release an enormous amount of energy in the form of radiation, kind of like firing an elastic band at someone with your fingers.

Unlike flares from the Sun, this flare emitted different kinds of radiation. It produced a huge surge of ultraviolet light and radio waves, known as 'millimetre radiation.' This suggests that stellar flares given off by red dwarfs are much more violent than previously expected. The type and amount of radiation given off by Proxima Centauri could make it very hard for life to survive on its orbiting exoplanets, which likely have no real atmosphere due to the powerful flares.

Above: Proxima Centauri is likely unsafe for life as we know it to exist

© NRAO

CLIMATE CHANGE HAS ALTERED THE EARTH'S TILT

Words by Meghan Bartels

Earth's poles are moving - that's normal - but new research suggests that within just decades, climate change and human water use have given them an additional nudge. Any object's spin is affected by how its weight is distributed. Earth's weight distribution is always changing as the planet's molten innards roil and its surface morphs.

Water is a key influencer, since it's so heavy. In the past two decades, two super-sensitive NASA satellite missions - the Gravity Recovery and Climate Experiment (GRACE) and its successor GRACE-FO - have analysed this shifting weight, but those observations only began in 2002.

In the new research, scientists focused on shifts in Earth's tilt in the 1990s, before that satellite data existed. Instead the researchers turned to observations of the water itself - measurements of ice loss and statistics on groundwater pumped out for human use - to combine with studies of how the poles drifted.

In 1995 polar drift changed direction completely, and between that year and 2020, the speed of the pole movement increased about 17 times compared to the average speed measured between 1981 and 1995. By combining the polar drift data with the water data, the researchers showed that most of the pole movement was triggered by water loss from polar regions - ice melting off land and flowing into the oceans - with smaller input from water loss in other regions, where humans pull groundwater up to use.

Left: Human water use and climate change are influencing natural shifts

© NASA

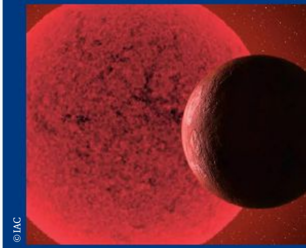
NEWFOUND SUPER-EARTH HAS A SPEEDY ORBIT AROUND A RED DWARF

Words by Daisy Dobrijevic

An exoplanet has been discovered 36 light years from Earth. GJ 740 b is three times the mass of Earth and orbits a red dwarf star called GJ 740. Each orbit takes just 2.4 days, making it the second-shortest orbit of any planet around a red dwarf star discovered so far.

Compared to our Sun, GJ 740 is tiny, between 0.08 and 0.45 solar masses. It's also far cooler, with estimated surface temperatures between 2,127 and 3,427 degrees Celsius (3,860 and 6,200 degrees Fahrenheit).

This duo is of particular importance due to its relative proximity to Earth. As such, the pair could find themselves the object of future observations using large telescopes such as the European Space Agency's Characterising Exoplanet Satellite (CHEOPS). Such observations could confirm whether the super-Earth is alone in its orbit around GJ 740. Cooler stars like GJ 740 make particularly good hunting grounds for new planets; scientists predict each of these stars has on average 2.5 planets in orbits of less than 200 days.



Right: It's not yet known if there are other planets in the same system

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On 21 July 1969, Neil Armstrong became the first man to walk on the Moon. The astronaut stepped onto the Moon's surface in the Sea of Tranquillity, nearly 20 minutes after first opening the hatch on the Eagle landing craft. Armstrong had reported the Lunar Module had landed safely the day before, with the words: "Houston. Tranquillity Base here. The Eagle has landed."

As he put his left foot down first, he made the iconic announcement: "That's one small step for man, one giant leap for mankind," which he said came to him without planning it ahead. He then went on to describe the surface as being like powdered charcoal, and that the landing craft only left a small indentation on the surface. The historic moments were captured on television cameras attached to the Eagle and were switched on by Armstrong himself. He spent the first few minutes on the surface taking photographs and soil samples in case the mission had to be aborted suddenly.

He was then joined by his colleague Edwin 'Buzz' Aldrin, and the two collected data and performed various exercises – including jumping across the lunar landscape – before planting the Stars and Stripes American flag.

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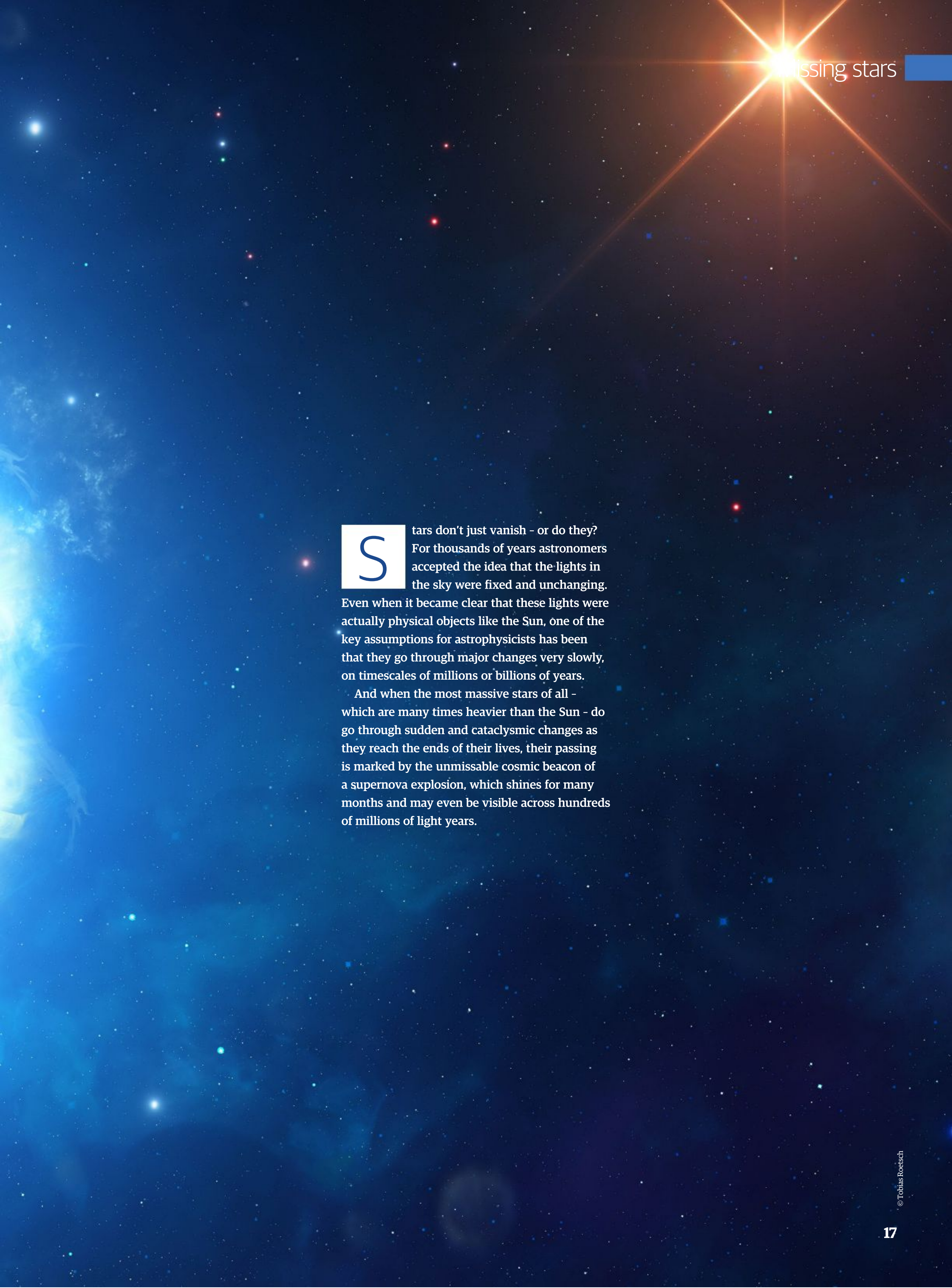
HUNT FOR THE UNIVERSE'S MISSING STARS

AN INTERNATIONAL TEAM OF ASTRONOMERS IS ON THE HUNT FOR OBJECTS THAT SHOULD BE IMPOSSIBLE

Reported by Giles Sparrow



Stars don't just vanish – or do they? For thousands of years astronomers accepted the idea that the lights in the sky were fixed and unchanging. Even when it became clear that these lights were actually physical objects like the Sun, one of the key assumptions for astrophysicists has been that they go through major changes very slowly, on timescales of millions or billions of years.

And when the most massive stars of all – which are many times heavier than the Sun – do go through sudden and cataclysmic changes as they reach the ends of their lives, their passing is marked by the unmissable cosmic beacon of a supernova explosion, which shines for many months and may even be visible across hundreds of millions of light years.

© Tobias Roetsch

But what if some stars suddenly just wink out of visibility? According to everything we know about stars, that should be impossible, but over the past few years a group of astronomers has set out to see whether such impossible things do happen, comparing data across decades of observations.

"VASCO is the Vanishing and Appearing Sources during a Century of Observations project," explains Dr Beatriz Villarroel of the Nordic Institute for Theoretical Physics, Sweden. "We're actually interested in all kinds of vanishing objects, but ideally I'd like to find a star that's been steady and has been there in the sky for as long as we can remember and as long as we have data for, and one day it just vanishes. And you can point the biggest telescopes in the world at it and still see nothing there."

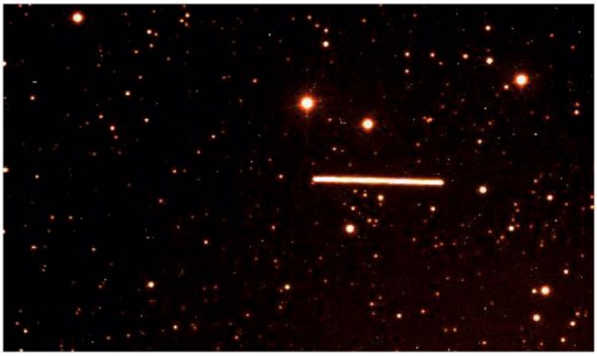
Since Villarroel and her colleagues began work on the project in 2017, they've attracted a lot of attention from scientists who see the potential in searching historic records: "We have astronomers from all kinds of different fields interested in the project - specialists in active galactic nuclei [the power source of intensely brilliant quasars in the distant universe], stellar physicists and SETI [Search for Extraterrestrial Intelligence] scientists - everyone has their reasons for getting involved."

Although our current understanding suggests that stars change only very slowly and dramatic disappearances should leave traces behind, that's not to say that all stars shine steadily. In fact, the sky is packed full of variable stars that pulsate and change in brightness. Villarroel emphasises that VASCO is about something different. "We know that there are variables, but their timescales tend to be a few years at most. We want to find something that goes from a completely steady star to just vanishing entirely - this hasn't been documented, and it's the kind of discovery that could lead to new physics."

Recent years have seen the development of automated telescopes that can catalogue the entire sky at a rate that previous generations of astronomers could only dream about. For instance, the Zwicky Transient Facility (ZTF) at Mount Palomar in California combines a state-of-the-art camera with the venerable Samuel Oschin Telescope. Its ultra-wide field of view enables it to survey the entire Palomar sky over just three nights, scanning the plane of the Milky Way twice each night. This massively increases the likelihood of detecting the chance eruptions known as transients - bursts of light that can be caused by intense stellar flares on distant stars, but may also be associated with some of the most violent and rare events in the universe, such as mysterious gamma-ray bursts.

Right: The VASCO researchers use data from the ESA's Gaia space observatory to double-check candidate 'missing' stars

Below: The USNO survey plates predate the Space Age, and exposures are long enough to distinguish asteroids as short trails against stars



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WHAT COULD THE 'MISSING STARS' BE?

Here are some of the potential explanations

© Tobias Roetsch

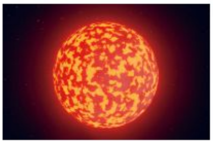
Failed supernovae

A failed supernova is a star - one far more massive than our Sun - which dies by collapsing into a black hole after a brilliant but short-lived explosion that could easily be missed. However, they're so rare that the VASCO hunt is unlikely to have detected even one in our galaxy.

© NASA

Flaring dwarfs

Low-mass dwarf stars shine dimmer than our Sun, but have strong magnetic fields that can produce huge stellar flares. If the earlier survey caught stars in the act of flaring, it might explain some apparent 'disappearance', but it seems unlikely to account for them all.



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New astrophysics

Perhaps we don't understand the universe as well as we think, and the missing stars are revealing aspects of stellar evolution that we've missed. These might even be due to an incomplete picture of fundamental physics, which governs the nuclear reactions that cause stars to shine.

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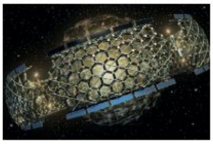
Interstellar beacons

Many candidates appear red. They could be red stars, but could perhaps also be lasers, tightly aligned packets of light deliberately beamed across the galaxy, perhaps for interstellar communication. The disappearance could be due to it switching direction, or being switched off.



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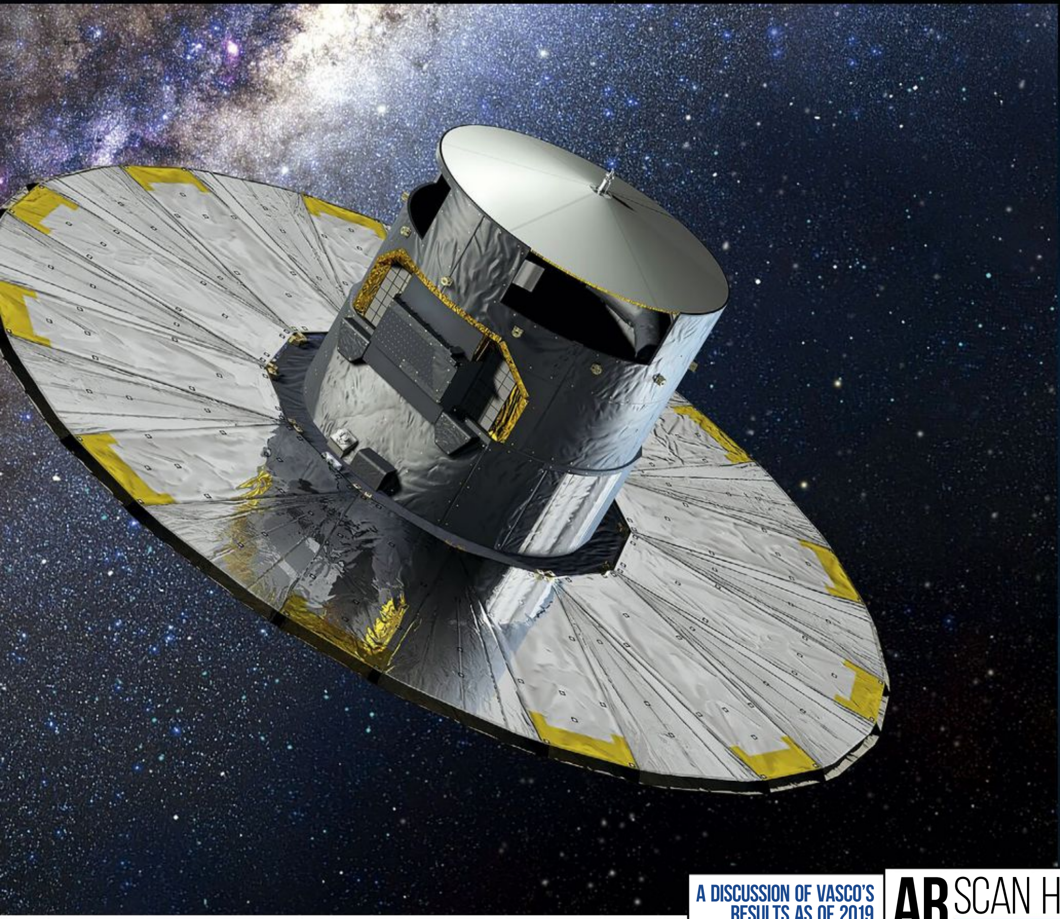
Alien construction

A really advanced alien civilisation could cause stars to disappear in a number of ways - perhaps blocking out their light by surrounding them with Dyson spheres or similar structures, or even deliberately destroying them to extract energy or for other unknown purposes.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Below: Ageing red giant stars can 'disappear' as they shed their outer layers and evolve into white dwarfs, but the process takes hundreds of thousands of years and produces a distinctive planetary nebula

A DISCUSSION OF VASCO'S RESULTS AS OF 2019

AR SCAN HERE

"I'D LIKE TO FIND A STAR THAT'S BEEN STEADY IN THE SKY FOR AS LONG AS WE CAN REMEMBER, AND ONE DAY IT JUST VANISHES" BEATRIZ VILLARROEL

However, there's a big difference between looking for stars that appear and those which disappear, as Villarroel highlights: "Projects like the ZTF work on very short timescales, but if you have a very rare event where something vanishes from the sky every hundred years then you really need a very long timescale to pick it up. In our case we want to find a star that has vanished – or actually appeared – using as large a time span as possible, combined with the best catalogues from older times. We're using data from 70 years ago and comparing it to data from today to see how the sky might have changed." Perhaps ironically, the team's search for high-quality historical data led researchers back to Palomar and the Samuel Oschin Telescope, which in the 1950s produced the photographic plates for an all-sky survey that has since been scanned by the US Naval Observatory (USNO). For a modern counterpart they relied on data from the twin telescopes of the Panoramic Survey Telescope and Rapid Response System (Pan-STARRS) at Hawaii's Haleakalā Observatory.

"All of these surveys are freely available, and everything has been digitised and is online,"

© NASA, ESA

MISSING STARS AND ALIEN ENGINEERS

Could VASCO's disappearing stars really be signs of aliens? We asked astrobiologist Dirk Schulze-Makuch

Professor Dirk Schulze-Makuch

Schulze-Makuch specialises in astrobiology – the science of possible life elsewhere in the universe – at the Technical University of Berlin's Center for Astronomy and Astrophysics.

As an astrobiologist, how do you make predictions about the possible behaviour of advanced alien civilisations?

That is very difficult to address. If we assume these civilisations consist of individuals, they can't be too aggressive and short-term thinking, because otherwise they would likely have become extinct. On the other hand, an advanced species must have fought itself to the top of the food chain in the past, so they can't be too docile and amicable either. But then we also have the example of swarm intelligence in our animal world, such as in a termite or ant state, a social structure which is also followed by some mammals, such as the naked mole rat. There are probably many other possibilities, so it is best to not have any preconceptions.

If the missing stars uncovered by VASCO are linked to advanced engineering by extraterrestrials, could we be looking at signs of Dyson spheres under construction?

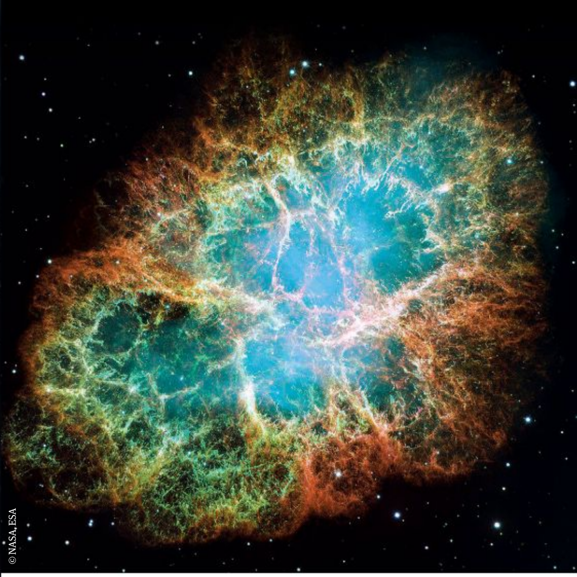
I don't think that would be Dyson spheres. In a paper from 2010 my former student Brooks Harrop and I showed that a Dyson sphere, as traditionally envisioned, would be physically unstable and collapse. Only modified versions could work, for example a swarm of satellites around a planet, but then those would be barely detectable. The Dyson sphere idea came up as an explanation for the dimming of Tabby's Star [the curious variable star discovered in 2015 by Tabetha S. Boyajian and her colleagues] for which we don't have a really convincing natural explanation yet. But we have to keep in mind that we are just beginning to explore the universe with modern telescopes, thus will not be aware of many natural phenomena and processes, and VASCO is a great tool to identify those.

What other sorts of advanced activity might explain the disappearances?

This is of course extremely speculative, as we don't know what an alien society would construct. For me something like artificial beacons for signalling over interstellar distances comes to mind, or even large generation-type starships that move from one place to another. Any kind of observed changes would be highly interesting because they would be caused by dynamic processes, either natural or artificial.

You've commented that if these phenomena are artificial in some way then it could help address the Fermi paradox – could you explain a bit about what that is?

The Fermi paradox may be better termed the 'Great Silence'. Our scientific assumptions have led us to assume that there are many habitable planets in the universe, boosted by the discovery of many exoplanets, and that Earth and the natural history of life on Earth is not a totally singular event. Then life, and also technologically advanced life, should be relatively common in the universe – yet we haven't found any firm evidence of it. There are so many possible explanations for this apparent paradox that some people wrote books about it. If we were to find something that is artificial, made by an intelligent entity, then it would resolve the ancient philosophical question: are we alone? It would mean we are not… with all its implications!



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Above: Massive stars can destroy themselves in supernovae, but these are hard to miss, outshining entire galaxies for several months and leaving behind superheated remnants

explains Villarroel. "Our IT team at Uppsala University has developed a citizen science webpage where you can click and combine images at **ml-blink.org**. We have computer game developers who have looked at making the design more appealing, and we also have an AI in development. There are several different ways of approaching the problem – whatever gives us data! The point is that people who are interested can go there to compare the images, and if they are very curious about some case they can leave a comment and we'll get back to them and inform them about their candidate. But we have quite a lot of work ahead of us before we can follow up on everything."

Every object in the USNO catalogue that is flagged as having no obvious counterpart in the Pan-STARRS data has to be examined and confirmed by the team. Researchers then look at the shape, brightness and other characteristics to identify whether it is a defect on the photographic plates of the original survey.

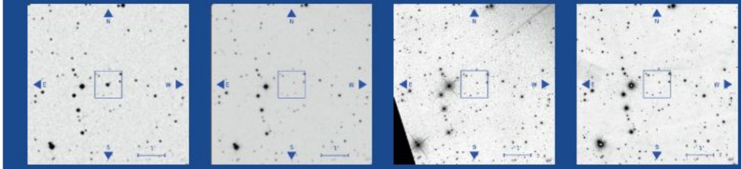
"You can never guarantee it's not a plate defect," Villarroel elaborates. "But you can do some tests in order to eliminate the most obvious things. Then you go to the deeper catalogues like the Sloan Digital Sky Survey (SDSS) or the new Dark Energy Camera Legacy Survey to see if you can find any remains of the object on these, and depending on what you find that might give you different types of candidates." The team also compares candidates with data from the European Space Agency's Gaia, which is currently busy gathering precision data for more than a billion stars in the Milky Way.

So far the survey has delivered more than 800 apparently 'missing' stars, many of which still need to be processed and studied in depth. And while there's no perfect match for Villarroel's ideal object – a vanishing act by a long-lived, stable star – many of the candidates that have been spotted are still intriguing in their own right.

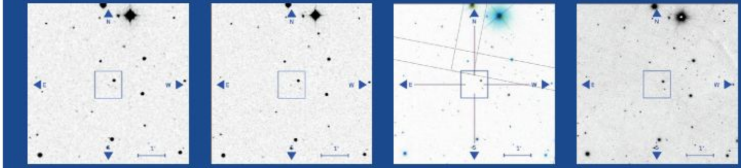
"We have found a number of short-lived transients that appear on one image and then not

CURIOUS CASE OF THE MISSING STARS

These mosaics showing the sky at different times reveal candidates



A bright object visible on a 1950 USNO plate (left) is missing from a plate taken in 1993 (middle left), as well as modern SDSS (middle right) and Pan-STARRS (right) data.



In this comparison, a faint star at the centre of the boxed area is present in both the 1950 and 1993 plates, but missing from the 21st-century surveys.

again. Those account for most of what we've found so far, but there are other things we're not sure of what they are yet. We've studied some of these short-lived transients, and they don't seem to be M-dwarf flares [the huge outbursts caused by the tangled magnetic fields of faint red dwarf stars that may cause them to brighten by a factor of a hundred or more] or any type of supernova. I think we can start excluding those options."

Other options that seem unlikely include variable stars and cataclysmic variables or novae – eruptions on the surface of white dwarf stars in binary systems. None of the sources sit close to a known variable, and the companion star in a nova system ought to be faintly visible on some of the modern surveys, even when the white dwarf isn't.

"One possibility is that they could be some kind of optical afterglow from gamma-ray bursts or fast radio bursts," ponders Villarroel. The sources of these high-energy cosmic eruptions are still poorly understood, but one common prediction is that as their energy output dwindles, they should pass through a brief period of visibility.

"Such outbursts are predicted to have super-big amplitudes of about eight to ten magnitudes, but fade in just a few minutes and don't seem to have any kind of visible counterpart when we look at the locations with big telescopes. Of course with 800 candidates we still have a lot of work to do, and I think to be clear it's almost certainly a mixed bag of objects of different types," she continues.

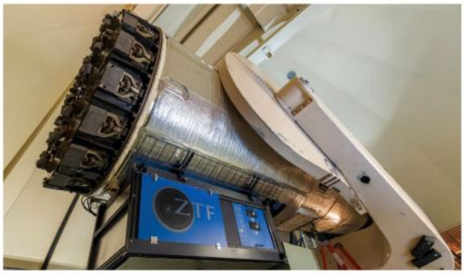
If those 800 candidates turn out to contain an ideal vanishing star, what could be the possible explanation? One option might turn out to be a so-called 'failed' supernova – a truly monstrous star with a core so massive that it collapses into a black hole and consumes the rest of the star from the inside out, cutting off the torrent of nuclear fusion that normally accompanies a supernova explosion and leaving no visible remnant behind.

However, Villarroel thinks that the odds are stacked against this explanation – she calculates that such events should happen about once every three centuries in our galaxy, making it unlikely that the VASCO project would stumble upon one by chance.

> "ONE POSSIBILITY IS THAT THEY COULD BE SOME KIND OF OPTICAL AFTERGLOW FROM GAMMA-RAY BURSTS OR FAST RADIO BURSTS" BEATRIZ VILLARROEL

Main: A failed supernova eruption is rapidly 'cut off' by the formation of a black hole at the centre of the dying star, but such events only happen in the Milky Way every few centuries

Right: The Zwicky Transient Facility is a sensitive wide-field camera that can spot short-term stellar outbursts



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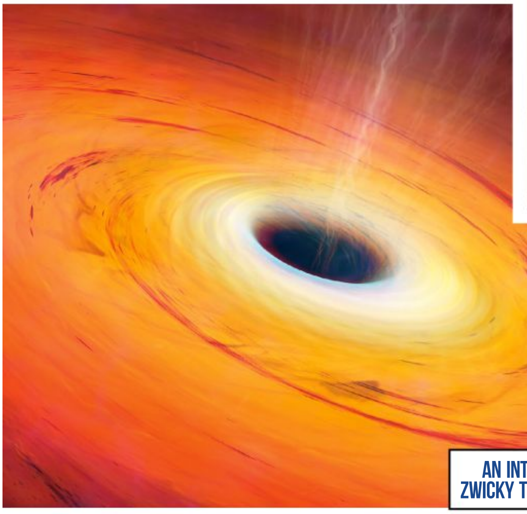

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AN INTRODUCTION TO THE ZWICKY TRANSIENT FACILITY

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At the moment it's hard to imagine other natural processes that might result in a star simply disappearing – and until a candidate emerges with features that can be studied, there's little point in speculating on possible new physics that might be involved in this cosmic vanishing act. However, that raises one other possibility that's inspired VASCO from the outset: the idea that apparently impossible astronomical events might give away the existence of advanced alien civilisations.

As increases in telescope size and sensitivity, coupled with computing power, have brought astronomy into its 'big data' era, many SETI scientists have argued that we're more likely to detect the presence of aliens through the otherwise-inexplicable behaviours of stars and other objects than we are from radio signals deliberately or accidentally beamed in our direction by alien life.

The theory is that if civilisations become sufficiently advanced, at least some of them are likely to develop the technology required for stellar engineering, which would alter the appearance of stars in otherwise-inexplicable ways. A classic example of this is the 'Dyson sphere' – a halo of orbiting power plants that would be the most efficient way of extracting energy from a star.

Science-fiction author Arthur C. Clarke stated in his Third Law that "any sufficiently advanced technology is indistinguishable from magic". If no natural cause for a stellar disappearance could be found, then the influence of intelligent extraterrestrials would certainly seem a more likely explanation than the supernatural.

"With regard to SETI, there are several different ways of thinking about it," Villarroel enthuses. "Dyson spheres and other structures, beacons that are turned on and off, or point in our direction for a certain time, or maybe there are ways for a civilisation to actually get rid of stars that are getting in the way."

Even the red transients that the team has identified so far could have a possible artificial cause: "Of course the first hypotheses we go for are natural ones – and we don't have any reason to exclude those yet – but if I was in my extraterrestrial speculation mode, I guess a laser beam could also produce a red transient of this type."

While Villarroel hints at exciting discoveries that have already emerged from the data and await formal publication, in the meantime the VASCO project continues. Many of the candidates identified so far still await proper confirmation and analysis, and only a quarter of the sky has actually been checked so far. Further progress will hopefully be accelerated by more volunteer citizen scientists and new automation methods currently being developed in collaboration with the Spanish Virtual Observatory.

"We don't know of any processes where a star would just vanish, except for this hypothetical failed supernova," Villarroel reflects. "Therefore vanishing stars become interesting because we haven't observed such things in nature. The main principle was to look for things we would think of as being impossible."

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Right: One extraordinary possibility is that the disappearing 'stars' are actually huge starships moving through space, in which case they might not be missing, but moving

Below: The Pan-STARRS survey telescopes at Haleakalā Observatory on the Hawaiian island of Maui

A History of the Universe in 21 Stars (and 3 Imposters)

Giles Sparrow's new book tells the story of the cosmos – and astronomy – through the tales of some of its most extraordinary stars.

Giles Sparrow

Space science writer

Giles has degrees in astronomy and science communication and has written many books and articles on all aspects of the universe.

> "MAYBE THERE ARE WAYS FOR A CIVILISATION TO ACTUALLY GET RID OF STARS THAT ARE GETTING IN THE WAY" BEATRIZ VILLARROEL

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HELP FEED FUTURE ASTRONAUTS

Space agencies need your assistance to keep spacefarers healthy on long-duration missions

Reported by Elizabeth Howell

NASA and the Canadian Space Agency (CSA) have paired up for a challenge to build food systems for Mars missions and other deep-space destinations. The Deep Space Food Challenge aims to generate new food production technologies or systems which would have little waste produced or resources required.

The reasoning behind this is that astronauts should be able to focus on their missions, having food production as only a secondary requirement so that they can focus on science - the main purpose of their work in space.

The ideal result will be food that is safe for long-term spaceflight and nutritious for astronauts - as well as tasty, which will encourage people to continue eating during long space voyages. These food systems and technologies may also be repurposed in places on Earth with poor food resources or for people who are living in isolated, confined environments like simulated space habitats.

"We are excited … to push the boundaries of food production technology that will help keep our future explorers healthy, knowing that some of these technologies could also have great terrestrial applications," Jim Reuter, associate administrator for NASA's space technology mission directorate, said.

NASA and the CSA each have their own application process, so pick the agency situated in the country where you are residing. People living in other countries may participate, but are not eligible for prizes. In all categories, Phase 1 submissions are due on 30 July 2021. In the US, NASA plans a $500,000 (£363,000) prize purse based on a Phase 1 food design. "Depending on the technologies presented, a possible second phase, involving a kitchen demonstration, could follow," the agency said.

The CSA plans a three-phase competition including a design report, a kitchen demonstration and a full system demonstration, with the grand prize winner announced in 2024. Finalists may receive a prize of up to CA$380,000 (roughly $300,000 USD or £220,000) along with interim cash prizes for Phases 1 and 2. For more information, head to **deepspacefoodchallenge.org**.

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> "WE ARE EXCITED TO PUSH THE BOUNDARIES OF FOOD PRODUCTION TECHNOLOGY THAT WILL HELP KEEP OUR FUTURE EXPLORERS HEALTHY"
> JIM REUTER

ROTATING SPACE STATION

They're a staple of science fiction, but a Californian company is planning to finally make them a reality

As we edge closer to sending humans to Mars, one of the great uncertainties is how our biology will cope with long exposure to little or no gravity. Crews will spend months in microgravity getting to the Red Planet, then potentially spend years in one-third Earth gravity on the surface. Microgravity causes all manner of physical problems, from muscle and bone weakening to changes in blood flow.

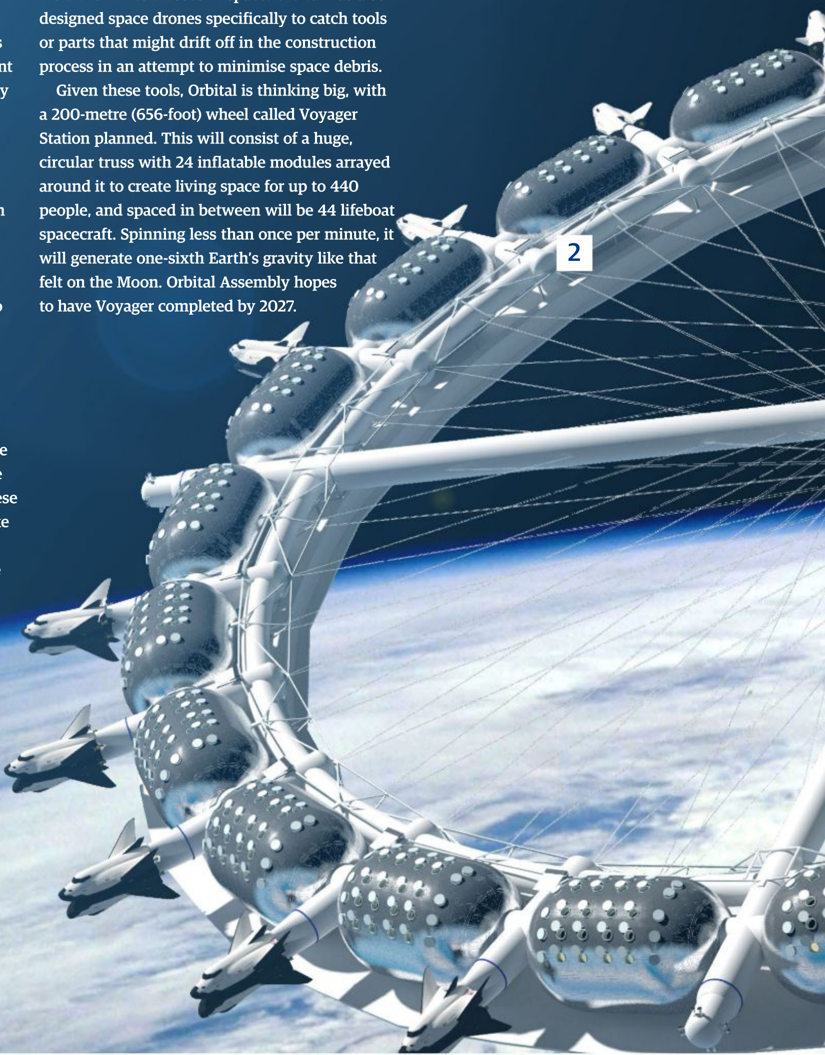
While microgravity is hugely useful for science in space, the ideal situation for humans working in space would be to create a significant gravity field to live in. We can't yet build gravity generators, but there is a technique we can use. First proposed by Konstantin Tsiolkovsky in 1903, spin gravity can make a gravity-like effect using a rotating structure. This uses the same effect as the perceived force we feel when a car goes around a corner or we spin on a roundabout: centrifugal force.

The bigger the structure of the spacecraft, the slower it spins to create effective gravity, so its less dizzying to the occupants. This could be accomplished by creating a large cylindrical structure, spinning on its long axis, with crew members living and working on the inside.

The classic spin gravity space station is a spoked wheel with a docking port in the middle to receive spacecraft and a toroidal living space around the outside. But a key problem with these concepts is the size of structure needed to make it work comfortably. The bigger the wheel, the slower it can spin, and therefore less difference in the 'gravity' experienced by your head and your feet, producing a more comfortable environment.

This is where Californian start-up Orbital Assembly comes in, working on the machines to build this huge Earth-orbiting outpost. Although Orbital Assembly ultimately aims to create a full station, the company has started with creating the tools to assemble it in space. The Structure Truss Assembly Robot (STAR) and Gateway Segment Assembly Line (GSAL) are free-flying robots which will take stock metal tubes and weld them into trusses in space. Orbital has also designed space drones specifically to catch tools or parts that might drift off in the construction process in an attempt to minimise space debris.

Given these tools, Orbital is thinking big, with a 200-metre (656-foot) wheel called Voyager Station planned. This will consist of a huge, circular truss with 24 inflatable modules arrayed around it to create living space for up to 440 people, and spaced in between will be 44 lifeboat spacecraft. Spinning less than once per minute, it will generate one-sixth Earth's gravity like that felt on the Moon. Orbital Assembly hopes to have Voyager completed by 2027.



1 CENTRAL HUB Orbital Assembly's robots will start by constructing a small ring-shaped truss to form the hub of the space station.

2 OUTER TRUSS The main structure of the ring will be a circular truss nearly 200 metres (656 feet) in diameter, assembled in orbit.

3 LIVING SPACE Orbital Assembly hopes to complete the Voyager Station in 2027. When complete it will be able to support up to 440 people.

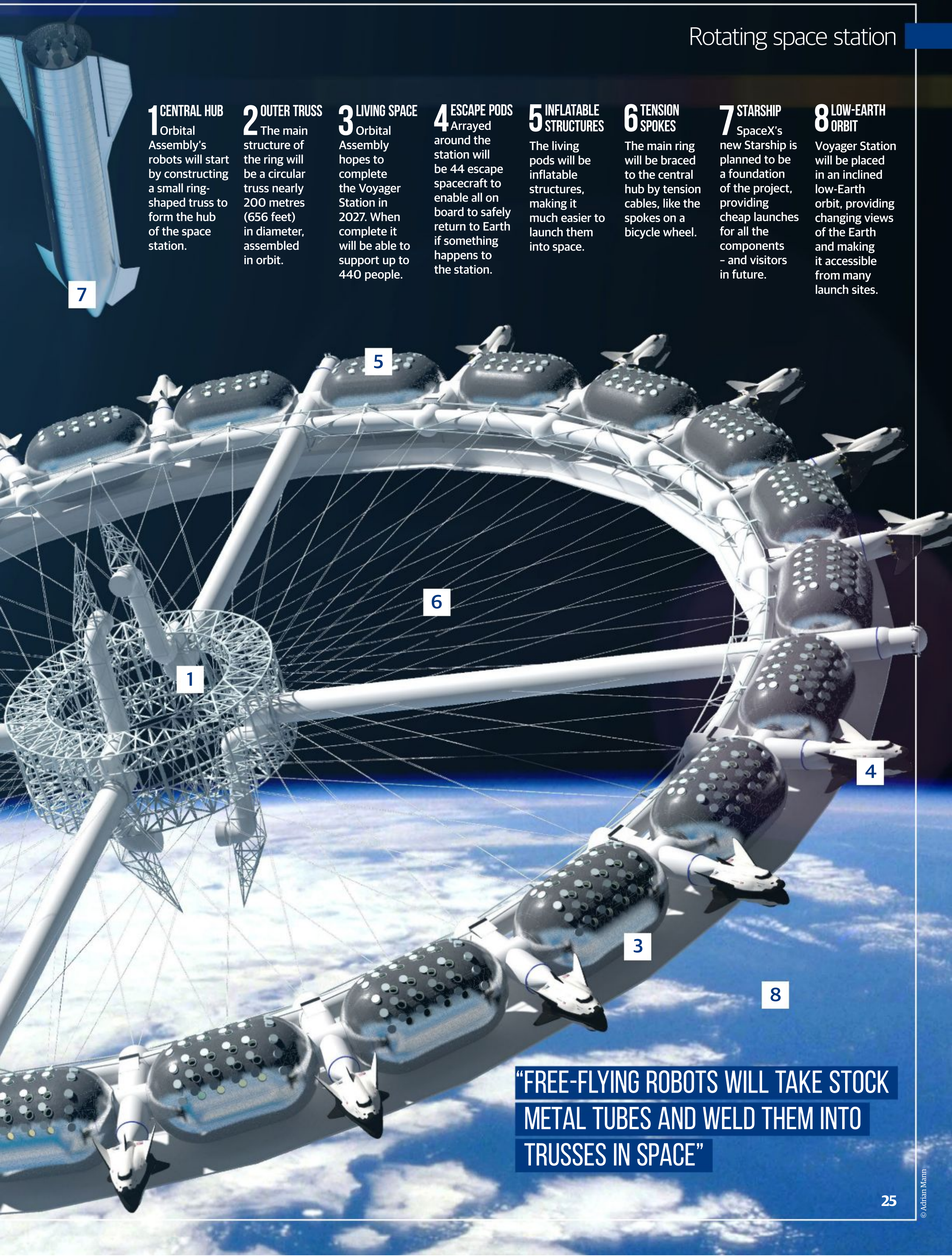
4 ESCAPE PODS Arrayed around the station will be 44 escape spacecraft to enable all on board to safely return to Earth if something happens to the station.

5 INFLATABLE STRUCTURES The living pods will be inflatable structures, making it much easier to launch them into space.

6 TENSION SPOKES The main ring will be braced to the central hub by tension cables, like the spokes on a bicycle wheel.

7 STARSHIP SpaceX's new Starship is planned to be a foundation of the project, providing cheap launches for all the components – and visitors in future.

8 LOW-EARTH ORBIT Voyager Station will be placed in an inclined low-Earth orbit, providing changing views of the Earth and making it accessible from many launch sites.



> "FREE-FLYING ROBOTS WILL TAKE STOCK METAL TUBES AND WELD THEM INTO TRUSSES IN SPACE"

© Adrian Mann

INTERVIEW

BIO

Jeremias Pfaff

Pfaff is studying towards a PhD at the University of Vienna. He is part of the Aspelmeyer Group, which explores the boundaries of quantum physics and gravity from both an experimental and gravitational perspective. The group has successfully measured the smallest gravitational force in the world by measuring the gravitational attraction between two gold spheres each spanning just two millimetres (0.07 inches) across.

JEREMIAS PFAFF

THE BOUNDARIES OF QUANTUM PHYSICS

Jeremias Pfaff speaks to **All About Space** about what it takes to measure gravity on such a minute scale. The next step? To go even smaller

Interviewed by Daisy Dobrijevic

Why can't physics describe how gravity works at a subatomic scale?

It might be able to, we just don't know yet. That's why we did this experiment, because it's mainly an experimental issue. Firstly, it's just really difficult to measure gravity. It's such a small force; you can imagine the gravity between the two spheres that we measure is 30 billion times smaller than the gravity that Earth pulls on one of the spheres. Just measuring that small force is tricky because you also have to shield it from all the other forces, such as magnetic and electrostatic, that are much stronger. If you can imagine a paperclip, the whole Earth is pulling on it, but just a little magnet is able to pull it up against the gravity of Earth - that's how much stronger the other forces are. It's just really difficult to measure on a small scale, so nobody has done it yet.

We know how gravity works. Newton and Einstein were mainly concerned about astrophysics, or the movements of the planets on big scales. However, on a smaller scale the quantum theory came along, and it describes the world in a very different way. We are going in the direction of measuring smaller and smaller objects with this experiment. But when we get to even smaller objects, the position of the object is not defined anymore by quantum physics. You might have heard of this Heisenberg uncertainty, where quantum objects can be at two or more positions at the same time. The theory of gravity from Newton and Einstein just does not account for this kind of thing. If you want to describe gravity, you must know the position of the object at all times. For small things, as far as we know through quantum mechanics, this isn't true. So what does the gravitational field look like for small things? We have no idea. The answer must be experimental, I think.

Why is it so important to understand gravity on such a small scale?

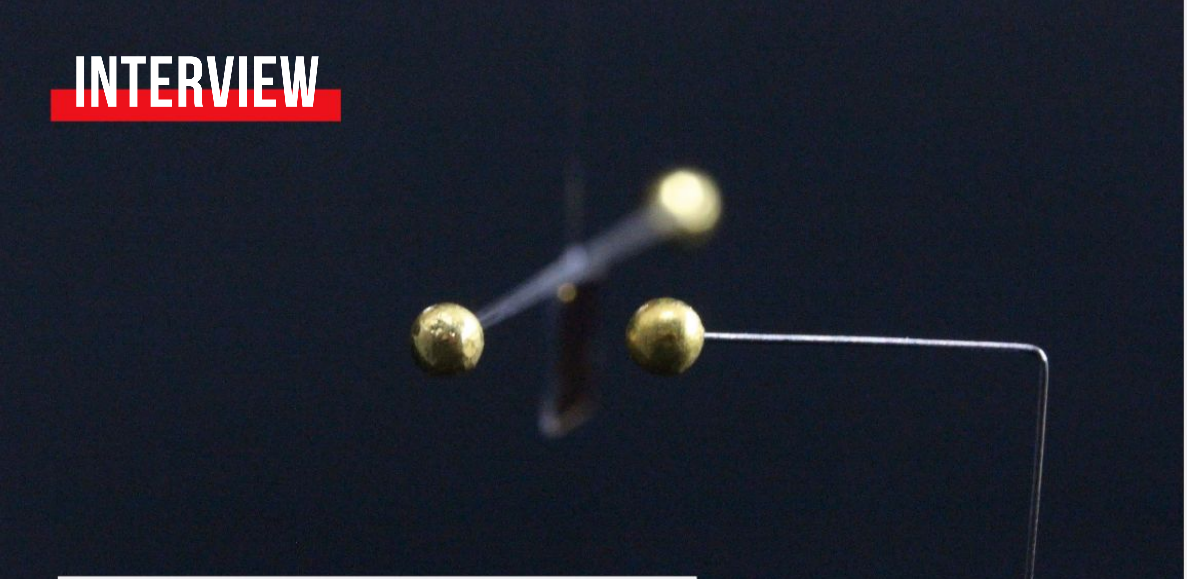
That's difficult to answer, because important means different things to different people. I think that there is a human curiosity to understand the world that is surrounding us, and that transcends the scientific community. For me it is just a very curious thing. However, if importance for you is the impact on your daily life or something like that, then I think that a better understanding of our world will at some point also have impact in our daily lives. Einstein, for example, didn't imagine the navigation systems on your phone, but it wouldn't work without his theories. At some point I think it will affect our daily lives, but it's not my main motivation. It is just my curiosity that drives me to understand how gravity works at small scales.

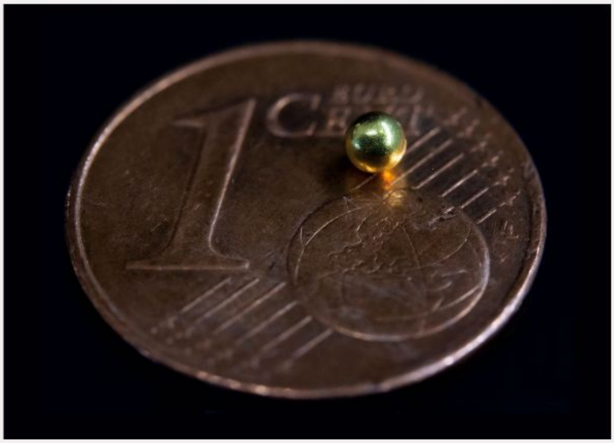
How did you measure gravity on a small scale?

It's an extremely simple principle. We just have an oscillator-like pendulum, a bit like a ball on a string, and this pendulum is suspended against the Earth's gravity, so it is free to move. If you now bring another object close to it, that will exert a force on this object. It will feel it and might move a little bit according to this force.

For example, if there were two magnets they might attract or repel. The same is true for any other force, and we wanted to measure gravity. To do this we used a special pendulum, not just a ball on a string, but more like a dumbbell shape with a stiff rod and two gold spheres on the end. This torsion balance idea goes back to experiments more than 200 years old by Henry Cavendish and other scientists at that time, who wanted to figure out the density of the Earth.

What's cool about the torsional balance we used in our experiment is that it won't rotate to all the other fields that are exerted by the environment. The horizontal bar with gold spheres on either end will only move when another gold sphere is moved





Above: Two gold spheres respond to each other's gravitational pull

Left: A tiny gold sphere used in the experiment

x3 Images ©Tobias Westphal/University of Vienna

closer to the horizontal axis of the bar, generating the gravitational force. We move the gold sphere close to the others and can modulate the force, and this will start to oscillate at the same frequency.

When you oscillate the object acting upon the torsion balance, is it easier to pick up a signal?

Yes, definitely, because we can define a certain frequency, and this frequency will show up in our data. If we just had a static signal where we move one sphere close to the other sphere, the pendulum would then slowly turn to this mass. This kind of experiment is also carried out by scientists, but the problem is that noise, such as urban noise, can get in the way of the static signal, whereas the oscillating signal with this frequency will be more dominant compared to the noise.

What challenges did you face? Does the environment influence the measurements?

That's why the torsional pendulum is so important to us, because if we just had a ball on a string we would have had even more environmental influences. For example, the local tram in Vienna will exert the same force as our tiny gold ball, even though it's 70 metres [230 feet] away. We could even see the vibrations of the Vienna City Marathon. The cool thing now is we don't have a linear oscillator, we have a torsional oscillator.

If you imagine a huge city tram 70 metres [230 feet] away, it will not cause the rotation, but it will cause the pendulum to swing. Only the small sphere close to the pendulum will induce the rotation, so this design choice allows for a very good discrimination between local forces very close to this torsion balance and all the other environmental effects. Even if you think about seismic effects, the Earth moving will introduce up-and-down motion, it will introduce side-to-side motion, but it won't introduce the rotation.

We have also put a huge amount of work into getting rid of surplus charges on the pendulum because the electrostatic force is so much stronger than the gravitational force. There is also a tiny electromagnetic shield between the pendulum and the moving mass.

The experiment also had to be carried out in a vacuum chamber, otherwise the air molecules wouldn't allow for this torsion motion. The torsion motion is always bouncing against the air molecules, which would dampen the movement of the pendulum, so we have to pump out as much air as possible. Everything has to be super sensitive.

Did you find gravity at this scale acted differently to larger scales?

No, gravity did work as we would have expected by Newton and Einstein. We didn't see any relevant deviations.

Does this mean you have to go smaller?

Yes, for us this was a proof-of-concept experiment. It's already smaller than everything that has been done so far for the smallest source mass. But our goal is to go much smaller, and already the next step will be a factor of 1,000 times smaller than this experiment.

This is interesting because a lot of the theories of dark energy or dark matter foretell deviations from Newtonian gravity. If we see these deviations that will of course be super spectacular, because one of these theories then might be right, and might give clues for us to further develop it. Or if we don't see any deviations, you can cross off a lot of these theories and invest your time into something more interesting.

Why did you use gold in your experiment?

If you look at gravitational laws, the denser the material, the more mass you can put in a specific size. Gold has a high density, is widely available and you can work with it easily. Making a small sphere out of gold is nice and easy.

There are a few denser materials, like osmium, for example, but it is also harder to get hold of and a lot harder to mould into a sphere. A lighter material would make our spheres bigger, but then they couldn't get as close, so the force would be weaker. That would make the experiment harder than it already is.

Can your research be used to shed light on other mysteries in our universe, like dark matter and black holes?

That's what we hope for. A big motivation to do this is getting the first evidence of what the gravitational field of a quantum object could look like and bridge this gap between quantum and classical theory. But let me stress there is still a long way to go, even with reducing the size of the spheres by a factor of 1,000 for our next experiment.

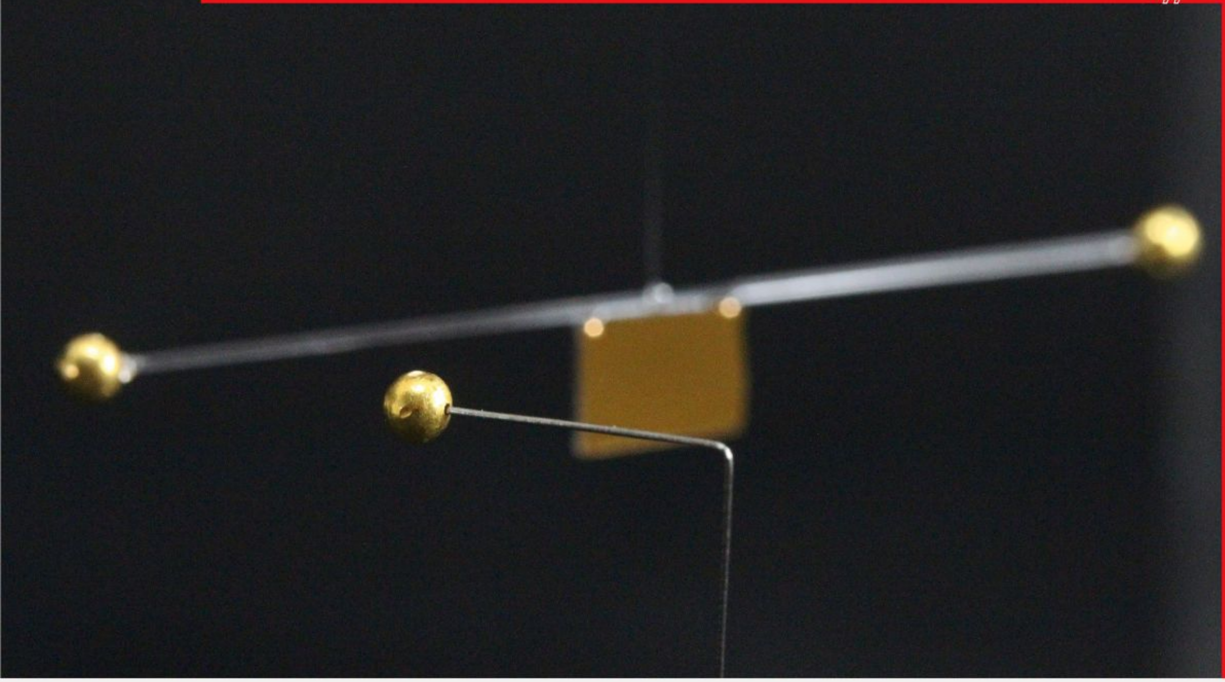
There are still many more years to go before we can control large enough objects in a quantum way by forcing them to be in two positions at the same time and measuring the gravitational field of this strange thing.

But as you mention dark energy and dark matter, these are also huge mysteries that need explanations. A lot of these theories predict that there are deviations from Newtonian gravity on smaller scales - on smaller mass scales and smaller distance scales. As we get closer, we can look into these theories and provide evidence for or against them. Of course, finding deviation from quantum gravity would be a spectacular result, but also excluding these theories would be helpful to understand mysteries like dark energy and dark matter.

Scientists are also looking at astronomical evidence for clues for dark matter and dark energy theories by working on getting quantum control over larger and larger objects. They are working from one side, getting the quantum world to bigger scales, and we are working from the other side, measuring gravity on smaller and smaller scales. If you want to bridge the gap between quantum theory and gravity, I think this is the way to go.

> “A BIG MOTIVATION TO DO THIS IS GETTING THE FIRST EVIDENCE OF WHAT THE GRAVITATIONAL FIELD OF A QUANTUM OBJECT COULD LOOK LIKE AND BRIDGE THIS GAP BETWEEN QUANTUM AND CLASSICAL THEORY”

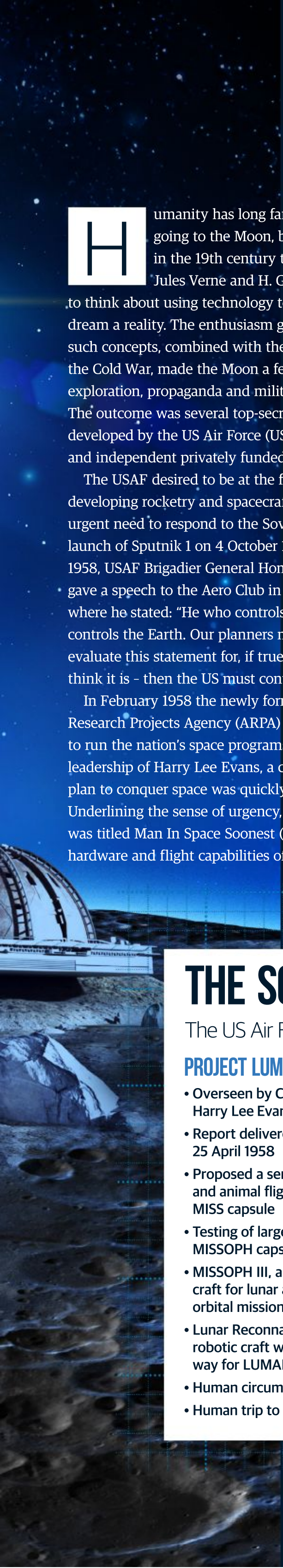
Below: The torsional pendulum used to measure the smallest gravitational force



FORGOTTEN PLANS TO REACH THE MOON

BEFORE APOLLO, MANY INGENIOUS LUNAR LANDING SCHEMES WERE PROPOSED THAT COULD HAVE CHANGED HISTORY

Reported by Nigel Watson



Humanity has long fantasised about going to the Moon, but it was only in the 19th century that writers like Jules Verne and H. G. Wells began to think about using technology to make this dream a reality. The enthusiasm generated by such concepts, combined with the heating up of the Cold War, made the Moon a feasible target for exploration, propaganda and military exploitation. The outcome was several top-secret schemes developed by the US Air Force (USAF), US Army and independent privately funded contractors.

The USAF desired to be at the forefront of developing rocketry and spacecraft, feeling the urgent need to respond to the Soviet Union's launch of Sputnik 1 on 4 October 1957. In January 1958, USAF Brigadier General Homer A. Boushey gave a speech to the Aero Club in Washington, where he stated: "He who controls the Moon controls the Earth. Our planners must carefully evaluate this statement for, if true - and I for one think it is - then the US must control the Moon."

In February 1958 the newly formed Advanced Research Projects Agency (ARPA) chose the USAF to run the nation's space programs. Under the leadership of Harry Lee Evans, a comprehensive plan to conquer space was quickly put forward. Underlining the sense of urgency, the proposal was titled Man In Space Soonest (MISS). The hardware and flight capabilities of a simple one-person, cone-shaped capsule would be tested in six robotic flights, followed by six more missions using animals to test life-support systems. Once these tests were passed, manned flights would begin. They would check out guidance and control systems, re-entry techniques and would culminate in a parachute landing at sea.

The next phase would have been the Man In Space Sophisticated (MISSOPH) program. This had three stages. The first was robotic and animal testing of a capsule that could stay in space for two weeks - the time it would take to make a Moon trip. MISSOPH II would send a spacecraft to a distance of 64,374 kilometres (40,000 miles), and test how it would cope with a re-entry speed of 38,405 kilometres (23,864 miles) per hour, the speed a craft returning from the Moon would achieve. MISSOPH III would test a shuttle that would land back on Earth like an aircraft and was planned for lunar and Earth orbital missions.

Alongside the MISSOPH missions, starting in April 1960 the USAF would have run the Lunar Reconnaissance (LUREC) program using robotic craft. LUREC I would test tracking and communications with a spacecraft 402,336 kilometres (250,000 miles) away, while LUREC II would test the guidance systems to ensure they could accurately land a craft at a specific place on the Moon. These craft would capture TV images and gather scientific information about the Moon to enable planners to select suitable landing sites. Then LUREC III, using retrograde rockets to land on the Moon, would send back further data.

It was only after those phases that Project LUMAN would come into play in May 1962. LUMAN I would send animal flights around the Moon to test the hardware and systems before LUMAN II sent astronauts on a circumlunar flight. LUMAN III would send robot craft to land a payload on the Moon, and LUMAN IV would land on the Moon and return to Earth.

It was with LUMAN V, planned for 1965, that a single astronaut would ride a 'Big B' rocket to make the momentous journey to the lunar surface and

> "IT TOOK A VERY SPECIAL SET OF CIRCUMSTANCES TO MOTIVATE SPENDING BILLIONS ON A LANDING PROGRAM" MICHAEL NEUFELD

THE SCRAPPED PROJECTS

The US Air Force, Army and private contractors produced these major studies before NASA took charge

PROJECT LUMAN

- Overseen by Colonel Harry Lee Evans
- Report delivered on 25 April 1958
- Proposed a series of robotic and animal flights of a simple MISS capsule
- Testing of larger MISSOPH capsule
- MISSOPH III, a lifting-body craft for lunar and Earth orbital missions
- Lunar Reconnaissance (LUREC) robotic craft would prepare the way for LUMAN missions
- Human circumlunar flights
- Human trip to the Moon

PROJECT MALLAR

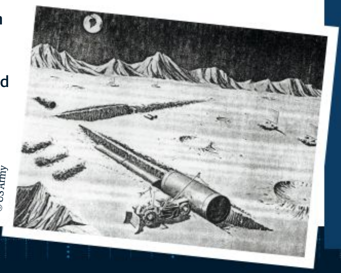
- Pioneered the lunar orbit rendezvous (LOR) concept
- Proposed using different mission modules
- Would require a space station, entry vehicle and assembly vehicle to prepare the mission for the lunar astronauts.
- Would take three to six days to go to the Moon
- Astronauts would spend 24 hours on the Moon
- Another three to six days to return home

PROJECT HORIZON

- The main intention was to create a lunar military base
- Proposed assembling spacecraft in low-Earth orbit
- Involved 40 Saturn V rocket launches before cargo delivery to the Moon
- Target was to land two astronauts on the Moon in 1965
- A permanent 12-person outpost would be operated from late 1966

PROJECT LUNEX

- A direct flight to the Moon
- Would require a huge three-stage rocket booster
- Would carry three astronauts using a shuttle-type spacecraft
- A target date of a 1967 Moon landing



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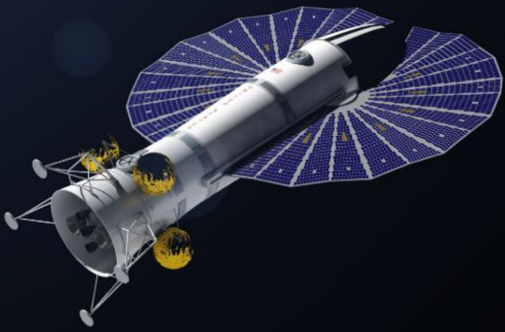
FORGOTTEN CRAFT

Inside the proposals that Apollo beat to the punch



PROJECT LUNEX

Having Project LUMAN rejected, the Air Force's Space Systems Division (SSD) worked on Project Lunex. Its 1961 report envisaged that a cargo version would be used to support the manned missions and to build a 21-person underground lunar base.

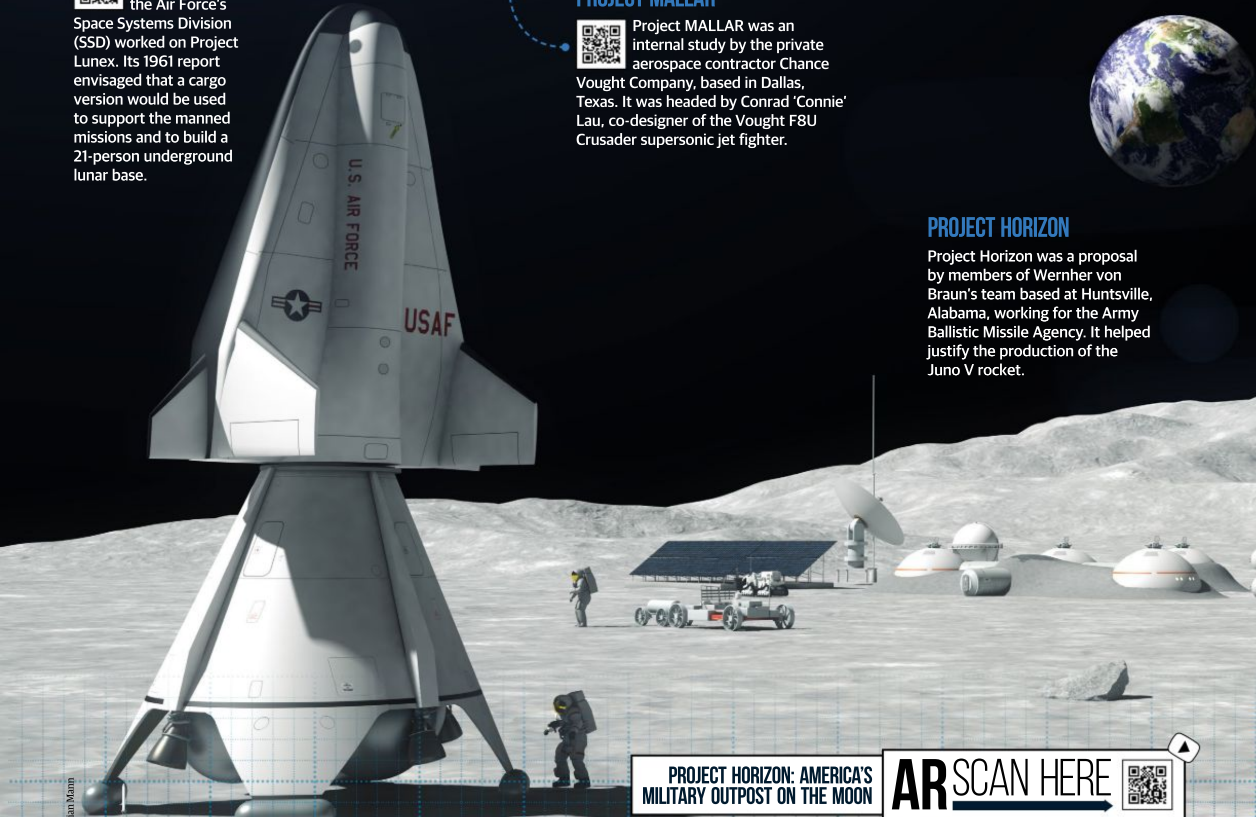
SCAN HERE FOR AR MODELS

PROJECT MALLAR

Project MALLAR was an internal study by the private aerospace contractor Chance Vought Company, based in Dallas, Texas. It was headed by Conrad 'Connie' Lau, co-designer of the Vought F8U Crusader supersonic jet fighter.

PROJECT HORIZON

Project Horizon was a proposal by members of Wernher von Braun's team based at Huntsville, Alabama, working for the Army Ballistic Missile Agency. It helped justify the production of the Juno V rocket.



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PROJECT HORIZON: AMERICA'S MILITARY OUTPOST ON THE MOON

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THE PATHWAY TO APOLLO

Numerous manned and unmanned missions made way for the program

© Adrian Mann

4 OCTOBER 1957

The Soviet Union launched the first artificial satellite, triggering what became the Space Race between the US and the Soviets.

12 APRIL 1961

Yuri Gagarin became the first man to travel into space. He made one orbit of Earth during the 108-minute mission.

25 MAY 1961

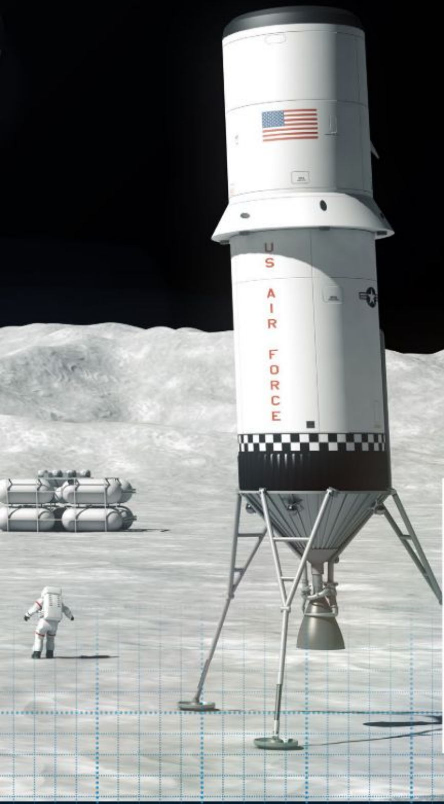
Having suffered humiliation at the Soviet Union's dominance of spaceflight, Kennedy announced his goal of landing a man on the Moon by the end of the decade.

1961-1963

On 20 February 1962, John Glenn became the first US astronaut to orbit Earth in the one-man Mercury capsule. The six manned Mercury flights established a foothold for NASA.

1961-1965

Of the nine Ranger robot craft, three were deliberately crashed into the Moon to collect more than 17,000 images of the lunar surface.

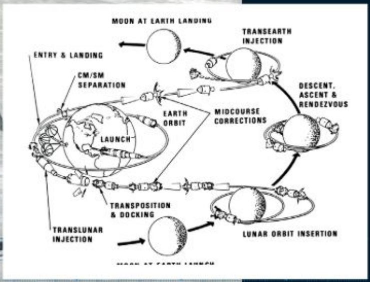


PROJECT LUMAN

Part of an ambitious Air Force plan by a team of about 60 people, it outlined a series of Man in Space Soonest (MISS) missions aimed at achieving a manned lunar landing and return.

© NASA

Above: The Lunar Module, with Earth behind, approaches the Apollo 11 Command Module after its successful Moon landing



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Above: Diagram showing the stages of the Apollo Moon missions, which used the LOR technique

back. The report was met with little enthusiasm, and was criticised for being too grand. It was felt that the USAF should rule out any interest in lunar missions and that any of its space projects should have a military requirement.

In December 1958, the aerospace contractor Chance Vought's astronautics division, under the direction of Thomas Dolan, put together a team to study vehicle concepts that could follow NASA's Mercury program. It quickly put an emphasis on possible lunar missions, and Conrad 'Connie' Lau was put in charge of Project MALLAR (MAnned Lunar Landing And Return).

The beauty of this scheme was that it involved using modular components and the use of rendezvous and docking techniques. It featured a two or three-person entry vehicle module that for Earth orbital missions would be attached to a payload module that could act as a space station for 14 days. For a lunar landing mission the modules for it would be assembled in Earth orbit and feature a two-person entry vehicle, a lunar mission module, a lunar landing module and a rocket stage to send it to the Moon. In lunar orbit the two-astronaut crew would transfer to the lunar landing module and descend to the Moon.

After 24 hours they would return to the orbiting modules, jettison the ascent stage of the lunar lander and return to Earth. The lunar mission module would be left in Earth orbit if desired, and the astronauts would use the remaining entry vehicle to get home. To provide electrical power it had a circular solar array that fanned out from the craft after launch, and it had spherical propulsion tanks attached to the outside of the craft.

The most important aspect of the design was that by using a lunar orbit rendezvous (LOR) technique, rather than sending a craft directly

1965-1966

Using a two-man capsule, Gemini was used for long-duration missions and to perfect rendezvous and docking manoeuvres necessary for the Apollo program.

3 JUNE 1965

Ed White became the first US astronaut to walk in space during the second manned Gemini mission.

1966-1967

A total of five Lunar Orbiter robot craft were sent to orbit the Moon to photograph it in even more detail. They also captured images of the far side to create an atlas of its whole surface.

1966-1968

Five Project Surveyor craft soft landed on the Moon to test the stability of the lunar surface, taking more than 87,000 images.

1968-1972

Conducted 11 manned missions. Apollo 7, 8, 9 and 10 tested the flight systems. Apollo 11, 12, 14, 15, 16 and 17 successfully landed and returned men to and from the Moon.

to the Moon, it would save 50 per cent of the total mission weight. At NASA, an LOR seemed too complex and dangerous, but John Houbolt, an engineer at Langley Research Center, worked hard at promoting the concept, and his MALLIR (MAnned Lunar Landing Involving Rendezvous) proposal was adopted for the Apollo program. Dolan failed to get any support from NASA for MALLAR, and further failures to attract any contracts involving Apollo led to his group fading from involvement in Moon landing missions.

Like the USAF's Project LUMAN, Wernher von Braun's team at the Army Ballistic Missile Agency saw the need to gain the military high ground by establishing a base on the Moon, which in addition could be used for scientific studies of the Moon and advancing further exploration of space.

Von Braun and his team thought that producing a large enough rocket booster for a direct Moon landing was impractical. He instead advocated for using a technique known as Earth orbit rendezvous (EOR). His Juno V - later renamed Saturn V - rockets would assemble a lunar rocket stage in Earth orbit that would rendezvous with a manned spacecraft. The manned craft would then be fired to the Moon by the rocket stage, and would slow down for a lunar landing when approaching the Moon. As early as 1952 he had put forward an ambitious plan to use EOR techniques to assemble three huge 3,964-tonne spacecraft that would take 50 astronauts to the Moon.

Less grandiose proposals for the base were detailed by von Braun's colleagues, Frank Williams and Heinz Koelle, in their 'Project Horizon' report submitted in June 1959. The report hedged its bets by proposing that a cargo of 2,721 kilograms could be soft landed on the Moon by the direct method, while crewed missions would be assembled in Earth orbit in conjunction with a space station.

Throughout 1964, 40 Saturn I and improved Saturn II boosters would prepare the way for a two-person Moon landing in April 1965. The building of the base would begin in earnest, with the delivery of 220 tonnes of cargo to the Moon by nearly 150 Saturn rockets. It was hoped that by November 1966 the base would be ready for a permanent 12-person task force. From December 1966 through 1967, a further 120 tonnes of cargo would be delivered to the base by 64 Saturn V launches. It was predicted that by the end of 1967, 42 astronauts would have been to the Moon and 26 would have returned after doing their stint of duty at the base.

> "THIS NATION SHOULD COMMIT ITSELF TO ACHIEVING THE GOAL, BEFORE THIS DECADE IS OUT, OF LANDING A MAN ON THE MOON" PRESIDENT KENNEDY

The base would consist of living quarters, a science laboratory, medical and communications facilities and storage rooms inside metal cylinders linked together and arranged in an L-shape. They would be buried beneath the surface and covered by lunar material to protect the occupants from radiation, meteoroids and the hostile lunar environment. Power would be provided by two nuclear reactors buried underground at a distance from the main base.

A surface construction vehicle would be used to dig the channels and position the metal living units into place, while another lunar rover would be used for cargo carrying and exploration. The base would be protected against intruders by handheld claymore mines and nuclear-tipped rockets. With the formation of the National

WHAT HAPPENED ON THE MOON BEFORE APOLLO?

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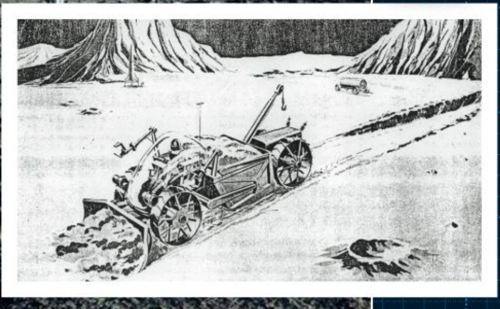
© NASA

Left: Apollo would be the program selected



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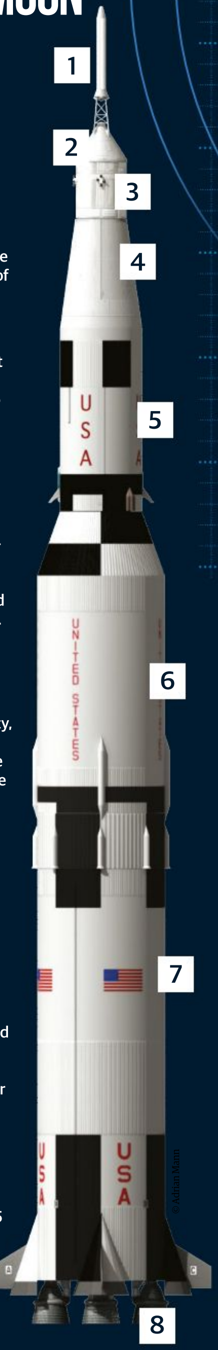
Below: The large open-wheeled construction vehicle, with a digger, crane and robot arm, imagined for building the Project Horizon Moon base

PROJECT APOLLO: HOW WE LAUNCHED TO THE MOON



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1 LAUNCH ESCAPE SYSTEM

Used in an emergency to blast the Command Module away from danger during launch.

2 COMMAND MODULE

Three astronauts controlled the spacecraft, living inside this module for most of the mission.

3 SERVICE MODULE

Carried life-support systems for the crew and a rocket engine to fire it into and out of lunar orbit.

4 LUNAR MODULE

Stowed above Saturn V's third stage, this vehicle had a two-person crew section and a lunar landing stage. It was protected by an aluminium cone.

5 THIRD STAGE

One J-2 engine boosted the speed to achieve escape velocity, putting Apollo into Earth orbit. It was able to reignite to boost the craft to the Moon.

6 SECOND STAGE

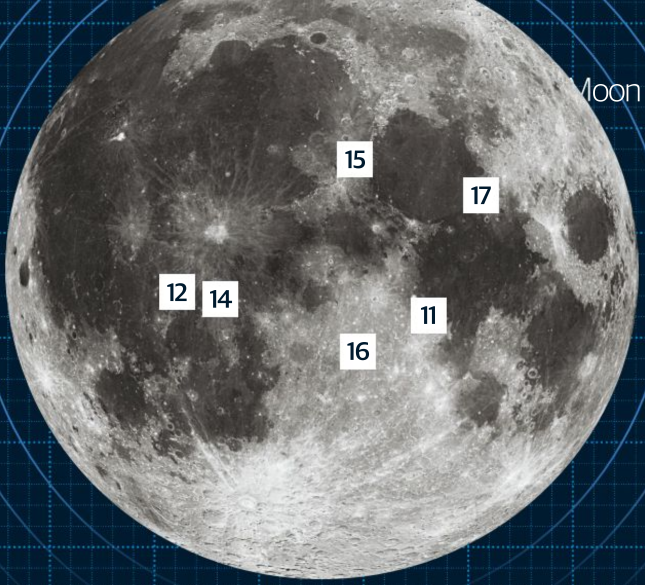
In six minutes the five J-2 engines accelerated Saturn's speed to over 24,140 kilometres (15,000 miles) per hour.

7 FIRST STAGE

The rocket achieved a speed of around 9,656 kilometres (6,000 miles) per hour in just 2.5 minutes.

8 F-1 ENGINES

Five F-1 engines gave an incredible combined thrust of 7.5 million pounds (3.4 million kilograms).



APOLLO 11	APOLLO 12	APOLLO 14	APOLLO 15	APOLLO 16	APOLLO 17
Neil Armstrong and Buzz Aldrin landed in the Sea of Tranquillity on 20 July 1969. Armstrong was the first to take one 'small step' on the Moon.	On 19 November 1969, Pete Conrad and Alan Bean landed in the Ocean of Storms.	Alan Shepard and Ed Mitchell landed in the Fra Mauro formation on 5 February 1971.	Landed near Hadley Rille on 30 July 1971. Astronauts Dave Scott and Jim Irwin were the first to use the lunar rover.	John Young and Charlie Duke landed in the Cayley Formation of the lunar highlands on 21 April 1972.	The last mission, crewed by Gene Cernan and Harrison Schmitt, landed in the Taurus-Littrow valley on 11 December 1972.

Aeronautics and Space Administration (NASA) in 1958, such projects were put under its leadership, and Project Horizon faded into history.

President Kennedy announced to Congress on 25 May 1961: "I believe that this nation should commit itself to achieving the goal, before this decade is out, of landing a man on the Moon and returning him safely to the Earth." The USAF optimistically put forward another Moon landing plan: the Lunex Project.

The aim was to send a crew of three astronauts to the lunar surface and back by August 1967. The plan intended to use a lifting-body spacecraft based on Boeing's Dyna-Soar delta-winged space plane program, which was cancelled in 1963. Using an Atlas rocket, it would begin with five test flights of scale models of the vehicle, followed in 1964 and 1965 with full-scale unmanned and then manned missions. Further tests would culminate in a robotic landing craft that would deliver cargo to the Moon in July 1966.

A circumlunar mission carrying astronauts would occur in September 1966, and only after further robotic testing of the whole system would astronauts go to the Moon. In 1968 a mixture of manned and cargo-delivering vehicles would establish an underground 21-person Moon base by July 1968. The project, like Project Horizon, was quickly rejected in favour of NASA's Apollo.

"The fact that these various ideas went nowhere is completely unsurprising. It took a very special set of political and international circumstances in 1961 to motivate the Kennedy administration to spend billions on a landing program," says Michael Neufeld, senior curator at the Smithsonian's National Air and Space Museum in Washington DC.

Although these projects came to nothing, they did have a major influence on determining the best way to get to the Moon. They certainly focused the debate over using a direct ascent, EOR or LOR technique to achieve a Moon landing. Once the LOR technique was agreed on by NASA, it determined the type of vehicles and techniques that needed to be built and tested to visit the Moon in the timeline dictated by Kennedy.

Nigel Watson

Space science writer

Nigel has written extensively about science and technology, in particular about extraterrestrial contact. He is the author of four books on alien life.

RISE OF VERA RUBIN'S SUPER OBSERVATORY

Astronomy's new era will be defined by a wider and deeper view of the universe

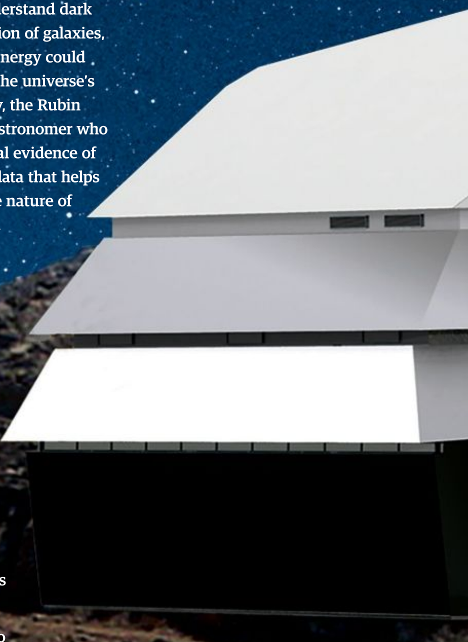
Reported by Robert Lea

The history of astronomy has been defined by advancements in telescope technology catching up with current theories and leapfrogging them, in the process providing new, exciting and challenging aspects of the universe to study. Telescopes have now reached the point where a single astronomer with a single telescope can make very little new headway. True astronomical innovation in the 21st century requires massive collaborations. The next leap in our observations of the cosmos is upon us, and will be delivered courtesy of a sizable undertaking: the Vera C. Rubin Observatory, currently under construction on the El Peñón peak of Cerro Pachón in northern Chile.

When Rubin begins operations in 2023, it will allow astronomers to consider some of the universe's most pressing mysteries, including assessing the nature of dark energy and dark matter. This will allow us to understand dark matter's influence on the evolution of galaxies, while the investigation of dark energy could reveal the driving force behind the universe's accelerating expansion. Fittingly, the Rubin Observatory – named after the astronomer who discovered the first observational evidence of dark matter – could deliver the data that helps us to finally understand the true nature of the universe's dark components.

© Rubin Observatory

Left: The mountainous terrain had to be moulded into a good spot to construct a telescope



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Left: Rubin will further research into dark matter in the halos of galaxies

© Rubin Observatory

> “WE EXPECT THE VERA C. RUBIN OBSERVATORY TO MAKE MANY DISCOVERIES – THINGS WE DID NOT EVEN KNOW EXISTED BEFORE” STEVEN KAHN

LSST: CONSTRUCTING A NEW ERA IN ASTRONOMY

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VERA RUBIN

© Getty

In the 1970s, while studying the Andromeda Galaxy, Rubin noticed it was rotating at a rate that seemed to defy Newton’s laws of motion. The astronomer had discovered the first direct evidence for dark matter, first theorised four decades earlier. Throughout her impressive career, Rubin was a tireless champion for women’s rights within the field of astronomy. It is only fitting that an astronomer may crack the secrets of dark matter using a facility named in her honour. And thanks to Rubin’s tireless struggle for equality, there is a good chance that this astronomer will be a woman.

In the distant cosmos, the observatory's intense gaze will uncover billions of galaxies and image them in stunning detail, while also allowing astronomers to view a similar number of hitherto unseen stars. Closer to home the observatory will also play an important role, conducting a survey of smaller bodies such as asteroids and comets within the Solar System. This detailed study of our own planetary system will help create a more comprehensive catalogue of near-Earth objects, providing knowledge that could potentially be key to mitigating collisions between our planet and potentially hazardous objects.

"There are four main scientific themes that have guided our design: cataloguing all of the small moving objects in the Solar System, mapping the structure and evolution of the Milky Way, investigating many kinds of stellar variability in the sky and determining the nature of dark matter and dark energy," Steven Kahn, director of the Vera C. Rubin project, tells **All About Space**. "These four themes have many individual facets to them and comprise many coupled investigations. But Rubin will enable other kinds of studies that are independent of these areas. We expect the Vera C. Rubin Observatory to make many discoveries – things we did not even know existed before."

That's quite a heady mix of undertakings, and certainly no small order for any telescope. It might leave you asking how one observatory will undertake large-scale investigations of so many different aspects of the universe.

These varying elements will be gathered under the umbrella of the decade-long Legacy Survey of Space and Time (LSST), which will build upon previous sky surveys. These studies, particularly the Sloan Digital Sky Survey (SDSS), Gaia and the Two Micron All-Sky Survey (2MASS), have formed the fundamental data pillar of astronomy for many years, systematically mapping the universe and providing insights that have shaped our understanding of the cosmos. But as impressive as these surveys and the telescopes that conduct them are, each is limited in the respect that they can only view a tiny fraction of the sky. This is one of the areas in which the Vera C. Rubin Observatory will really up the ante.

From its initial proposal, when it was named the Large Synoptic Survey Telescope, the design of the Vera C. Rubin Observatory's telescope – the Simonyi Survey Telescope (SST) – has been guided by three key watchwords: width, depth and speed. Above all of the SST's advantages, it is its wider view of the universe that is perhaps the most striking. It possesses a view so wide that it can observe the sky over half of the planet.

"The Rubin Observatory's SST will be very different from all the existing large telescopes,"

Above: The Vera C. Rubin Observatory sits at a 2,663-metre (8,737-foot) altitude

Right: In November 2015, one of the observatory's main columns is completed and coated in concrete

© Rubin Observatory

WHAT WILL THE RUBIN OBSERVATORY DO?

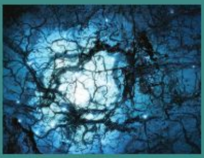
INVESTIGATING THE DARK UNIVERSE: DARK MATTER

One of the most exciting prospects offered by the Vera C. Rubin Observatory is the investigation of one of the universe's most mysterious aspects: dark matter. Vera Rubin offered the first evidence that as much as 85 per cent of galaxies' matter is tied up in a substance that doesn't behave like ordinary matter. Solving the mysteries surrounding its nature could help us to understand how galaxies are shaped.

© NASA/ESA

INVESTIGATING THE DARK UNIVERSE: DARK ENERGY

While dark matter's gravitational influence holds galaxies together, the influence of dark energy drives them apart at an accelerating rate, expanding the very fabric of space between them. Project director Steven Kahn says: "We believe that Rubin will deliver very tight constraints on our knowledge of the expansion history of the universe, which should help us to understand the nature of dark energy."



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SURVEYING THE SOLAR SYSTEM

The Vera C. Rubin Observatory will help astronomers better understand space on our doorstep by assisting them in cataloguing the Solar System's smaller inhabitants. Small bodies like those in the Kuiper Belt contain clues to the conditions in the Solar System before the planets formed. The Vera C. Rubin Observatory is perfectly equipped to study such objects due to its ability to precisely track moving objects.

© NASA

TRACKING TRANSIENTS

The observatory's impressive eye for change will be able to track changes in some of the most powerful events in the universe, like supernovae, best understood by watching how they change over time. While previous surveys have built an impressive fundamental understanding of how stars change throughout their lives, Rubin will follow in their wake with its impressive depth of vision, filling in gaps and solidifying this knowledge.

© NASA

THE MILKY WAY'S GALACTIC DIET

The Vera C. Rubin Observatory will allow astronomers to study the structure, composition and kinematics of the stars in our galaxy. Locked within these qualities and the distribution of main sequence stars is the history of the Milky Way. In particular, astronomers will be looking to model the growth of our galaxy's halo over time, likely revealing its history of cannibalising smaller galaxies.

© ESO

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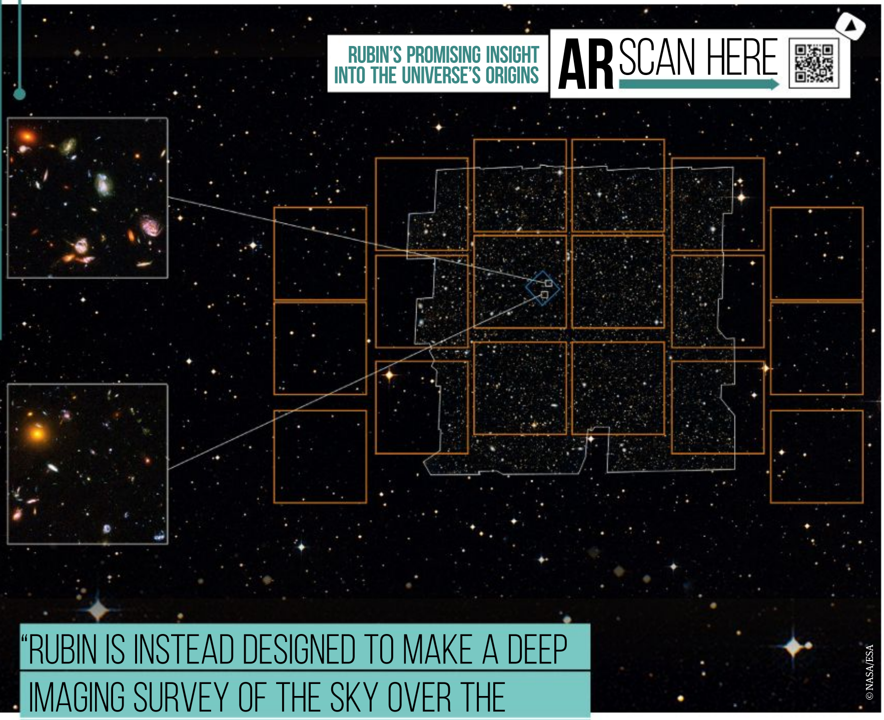


RUBIN'S PROMISING INSIGHT INTO THE UNIVERSE'S ORIGINS

AR SCAN HERE

© NASA/ESA

> "RUBIN IS INSTEAD DESIGNED TO MAKE A DEEP IMAGING SURVEY OF THE SKY OVER THE ENTIRE SOUTHERN HEMISPHERE" STEVEN KAHN

Kahn, also a professor of physics at Stanford University with a background in experimental astrophysics, says. "Most telescopes are designed to make detailed investigations of individual objects - stars, galaxies and clusters of such objects. Rubin is instead designed to make a deep imaging survey of the sky over the entire Southern Hemisphere."

The foundation of this wide-field view is the telescope's unique three-mirror design, with the primary mirror measuring in at an impressive 8.4 metres (27.6 feet). This design boosts what astronomers call the étendue of the system - a quality that is the product of the collecting area of the primary mirror and the field of view of the camera, describing how spread out the light in a system is. "The Rubin Observatory will have more than ten times the étendue of all previous facilities and all which are currently planned for development anywhere else in the world," explains Kahn. "It is unique in that sense."

In order to obtain such high étendue, the Vera C. Rubin Observatory team had to combine this unusual three-mirror optical system with the use of a record-breaking piece of kit - the largest digital camera ever created, which is about the size of a small car. This camera is also the first with a 3.2-gigapixel capability.

The camera will take one 15-second exposure of the sky every 20 seconds, enabling it to capture about 10,000 square degrees of the sky over the course of three nights on a single filter. This grants the Vera C. Rubin Observatory the ability to track moving objects and changes in transient objects and events like supernovae. Though this may sound relatively straightforward, it's actually incredibly complex due to the fact that the movement of objects close to Earth and the rate at which objects like stars change occur over an extreme range of time periods.

To put this into perspective, imagine using the same camera to track the growth of a tree and the movement of a squirrel as it scurries across its trunk. Fortunately, the observatory will have the ability to survey the sky on these radically different timescales, from years right down to around 15 seconds.

The Vera C. Rubin Observatory will also provide unprecedented depth by observing the universe in six different optical bands, with wavelengths ranging from 320 to 1,060 nanometres. That covers ultraviolet light right through the visible light spectrum to infrared. As a result the observatory will be able to image some extremely faint objects missed by previous surveys.

Above: Imaging half the sky at a time, Rubin will be able to glimpse further into space than ever before

VERA C. RUBIN OBSERVATORY BY NUMBERS

10,000 SQUARE DEGREES
The survey area that the system will image on a single filter over three nights

20 BILLION
The number of galaxies the observatory will view

3 TONNES
The weight of the observatory's 3.2-gigapixel camera

8.4
The telescope's primary mirror size in metres

5.2 MILLION
Exposures the SST's camera will take during its operation

6
The number of wavebands the telescope will make observations in

7 YEARS
The time it took to create the primary mirror

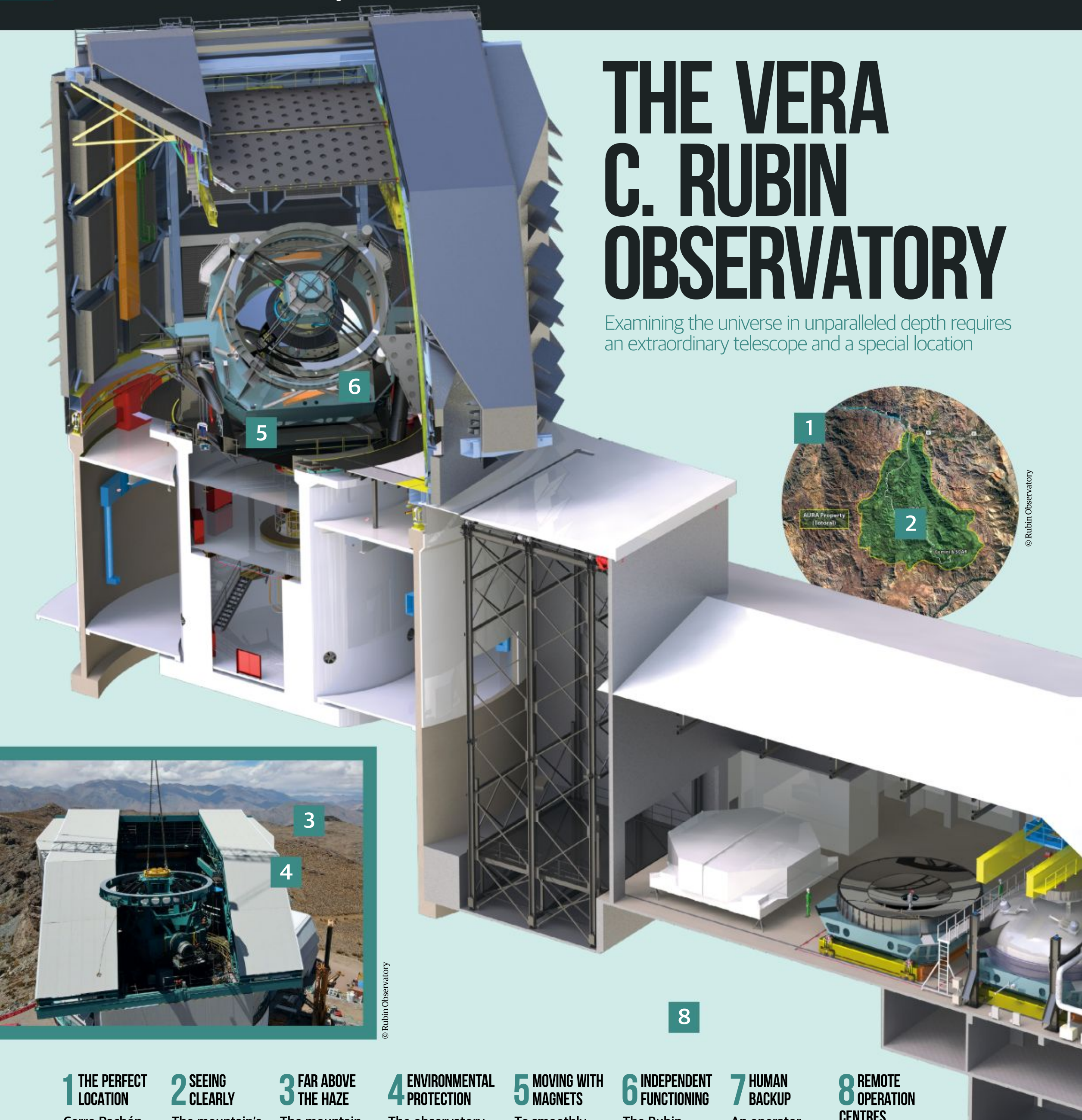
37 BILLION
Total number of objects that will be imaged by the observatory

9.6
The telescope's total field of view in square degrees

10 YEARS
The operating period for the observatory

THE VERA C. RUBIN OBSERVATORY

Examining the universe in unparalleled depth requires an extraordinary telescope and a special location



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1 THE PERFECT LOCATION

Cerro Pachón, a mountain in Chile, was selected as the site for the observatory in 2006.

2 SEEING CLEARLY

The mountain's dry nature and clear nights are perfect for conducting infrared observations.

3 FAR ABOVE THE HAZE

The mountain top is above Chile's summer haze, maintaining a clear view of the stars.

4 ENVIRONMENTAL PROTECTION

The observatory features light baffles, wind protection and natural ventilation to mitigate environmental effects.

5 MOVING WITH MAGNETS

To smoothly swivel between fields of view, the telescope is powered by magnetic motors.

6 INDEPENDENT FUNCTIONING

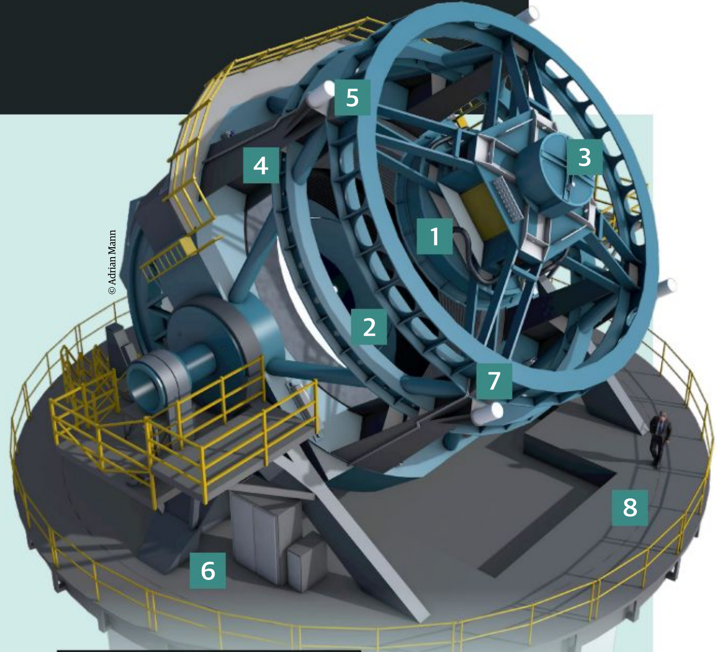
The Rubin observatory and its facility are totally automated and need very little human intervention.

7 HUMAN BACKUP

An operator will be on hand at the summit to back up the observatory's sophisticated software scheduler.

8 REMOTE OPERATION CENTRES

Researchers will be on hand to monitor progress at remote operation centres.



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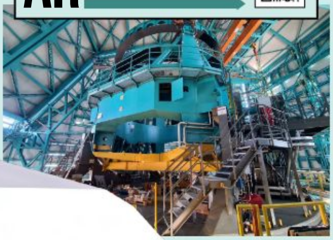

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1 TRIPLE MIRROR

The key to the SST's deep and wide view is its unique triple-mirror system.

2 SOMETHING TO REFLECT ON

The primary mirror, created by Steward Observatory Mirror Lab, has a unique honeycomb design.

3 RECORD-BREAKING MIRROR

The secondary mirror has a diameter of 3.4 metres (11 feet) and is the largest convex ever.

4 THAT'S ONE BIG CAMERA

The camera is the world's largest at three tonnes, with a width of 0.6 metres (two feet).

5 BIG IMAGES TOO

It's also the world's first 3.2-gigapixel camera. Displaying one image would take 378 4K TVs.

6 WEIGHING IN

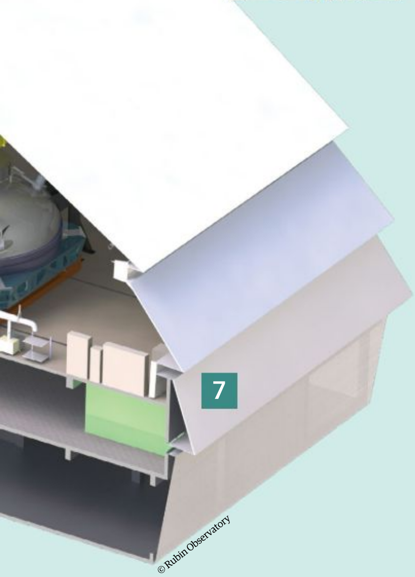
The total weight of the telescope is around 350 tonnes.

7 HOLDING IT TOGETHER

The mount is compact and strong, with four elevation drives and four balancing systems.

8 HEAVY BUT QUICK

The whole structure can reposition in just five seconds thanks to hydrostatic bearings.



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"Rubin will obtain nearly 1,000 images of every part of the southern sky. By comparing images taken at different times, we can detect everything that moves in the sky and everything that varies in brightness," says Kahn. "By adding together those 1,000 individual images, we can obtain the deepest images of every part of the southern sky."

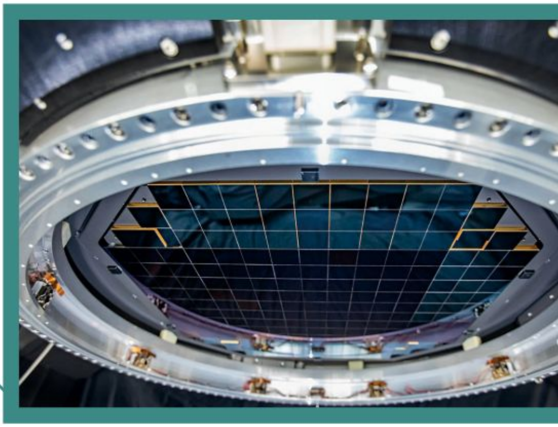
Kahn explains that this means that for almost every kind of known astrophysical system, the observatory will grant astronomers statistical samples which are 100 to 1,000 times larger than those available from past surveys. "That will enable scientists to conduct very sensitive statistical investigations of the properties of those systems," Kahn adds. "This will revolutionise our understanding in nearly all fields of astronomy."

"Rubin is unique in its capability to execute a highly sensitive, wide-field, time-domain survey in the optical/near-infrared – it has been specifically designed to execute such a survey, and this is what sets it apart from other telescopes," says Niel Brandt of the department of astronomy and astrophysics at Pennsylvania State University.

Collecting so many highly detailed images presents a major challenge, as it represents a lot of data that has to be handled. For Brandt, whose involvement with the development of the Vera C. Rubin Observatory began in 2005 when he championed Penn State's contribution to the project, this data handling was one of the key problems that had to be tackled by the team.

"The main challenge will be dealing with the nightly flood of around 20 terabytes of data that will come from Rubin. Specifically, how can this data be turned into exciting science discoveries in a timely and economical way? The challenges will be overcome with a lot of hard work, especially by astronomers, who will continue to learn new techniques in managing and building

Below: Rubin has a massive 8.4-metre (27.6-foot) primary mirror that took seven years to construct



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Left: Rubin will observe in six wavelengths, allowing it to observe most of the cosmos

Below: The observatory's final structure begins to take shape in this image taken in March 2021

© NASA/ESA

THE VERA C. RUBIN OBSERVATORY

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> "WE CAN DETECT EVERYTHING THAT MOVES IN THE SKY AND EVERYTHING THAT VARIES IN BRIGHTNESS" STEVEN KAHN

© Rubin Observatory

code, machine learning, data management, image processing, statistics, visualisation and communication," Brandt surmises.

Thus the Vera C. Rubin Observatory required another revolution just to process the sheer wealth of information it would yield. "We also had to develop the technology to process all of that data, to store it and to enable scientists to query it in order to conduct their investigations," Kahn says. "All of that was new and is beyond state of the art."

Over the ten years that the Vera C. Rubin Observatory will conduct the LSST survey, many further advances are likely to be made in the field of telescope technology. It may come as a surprise to learn that the project won't really attempt to keep pace with these developments. However, there is a very good reason for maintaining telescope consistency.

"We want the ten-year survey to be relatively uniform in time and space, so we're not expecting to change the hardware over that period of operation," Kahn says. "There will undoubtedly be new advances in detector and telescope technology, but we will not implement them. Our system is designed to operate for ten years."

That doesn't mean that the observatory will be at a complete standstill, however. There are still improvements that could be implemented, particularly in the data handling side of its operations. "There likely will be major advances in data analysis techniques and methodologies over that ten-year period," the project director says. "We will implement those, and we expect our capabilities to improve dramatically with time."

With such a wide range of investigations stemming from one observatory, it's understandable that the project brings together scientists from across a multitude of disciplines, and each brings with them their own 'wish list' of mysteries they would most like to see the Vera C. Rubin Observatory solve.

"I am most interested in studies of growing supermassive black holes which manifest themselves as active galactic nuclei (AGN)," says Brandt, who currently serves as chair of the Active Galactic Nuclei Science Collaboration. "I want to learn about the physical processes operating in AGN, the demographics of AGN over cosmic history and the interactions between AGN and the galaxies hosting them."

For Kahn, part of the beauty of the project is that no one is quite sure what will be discovered in the data it provides: "We don't know what we will find. That is the rationale behind building the experiment in the first place." The astrophysicist does know one thing for sure, however, the sheer scale of the project and the impact it will have on astronomy is tremendous. "Rubin will detect and catalogue something like 20 billion galaxies, meaning for the first time we will know about more galaxies than there are people on Earth."

Kahn explains that this is an interesting number because it represents roughly ten per cent of all the galaxies estimated to exist in the observable universe. "The observable universe is finite, because as we look further out into space, we are looking further back in time, and eventually we get to a time before galaxies first formed," the project director concludes. "It will be a remarkable human achievement to be able to make such a record of our universe this way, equivalent in some respects to some of the first maps ever made of the entire Earth. It is very exciting to be part of this project."

Robert Lea
Space science reporter
Rob is a science writer with a degree in physics and astronomy. He specialises in physics, astronomy, astrophysics and quantum physics.

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IS OUR SUN GOING INTO HIBERNATION?

Each sunspot cycle has been getting less intense. Is our star falling asleep?

Reported by Kulvinder Singh Chadha

Solar activity refers to the state of the Sun's magnetic field and associated phenomena: sunspots, flares, solar wind and coronal ejections. During periods of minimal solar activity, such events are often uncommon and weak. During solar maximum, they're at their strongest and most frequent. Magnetic field fluctuations on the Sun can happen on drastically different timescales, ranging from seconds all the way to billions of years. When astronomers speak of a 'slow down' or a period of quiescence in the Sun's activity, it doesn't mean the Sun will stop shining, but that there's a slow down in activity.

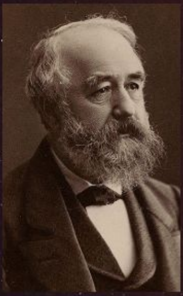
The Sun has one particular rhythm, lasting approximately 11 years, in which its polar magnetic field flips polarity. Sunspots serve as an indicator of this change. Indeed, it's often known as 'the sunspot cycle'.

Although sunspots themselves were first observed by Galileo, Christoph Scheiner and others from 1609 onwards, the cyclical nature of their appearance and disappearance was first noted in 1775 by Danish astronomer Christian Horrebow. It was then rediscovered in 1843 by Heinrich Schwabe. In 1848, Swiss astronomer Rudolf Wolf used Schwabe and others' results, as well as performing his own observations, to calculate the 11-year cycle and a mathematical method to count the number of sunspots. This so-called 'Wolf number' remains in use today.

Many other astronomers at the time either independently observed this cycle or were inspired by the results of others. Wolf's own calculation of the 1755 to 1766 sunspot cycle was labelled as the first, and each sunspot cycle since then has been progressively numbered as such. We are now in Cycle 25.

But sometimes the spots don't appear at all. This was the case for 80 days of the first six months of the current solar cycle, which started in December 2019. It was greater still for the same period in Cycle 24, where there were 139 spot-free days. The period from 1645 to 1715 saw a near-total crash in sunspot numbers, where they could literally be counted on two hands.

Wolf struggled to piece together solar cycles before the mid-1700s because of this dearth of information, but it didn't mean sunspots weren't



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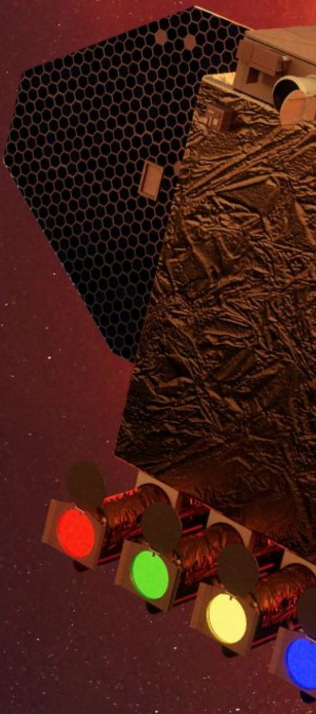
Left: The modern numbering of solar cycles comes from Rudolf Wolf, who studied them back to 1755



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being observed. Many distinguished astronomers of the age, such as Giovanni Cassini, continued to make observations. This 70-year solar lull was later noted by German astronomer Gustav Spörer, which then later inspired the British-Irish husband and wife team Edward and Annie Maunder. The period has since been named the Maunder minimum. There have been other lulls before and since, such as the Spörer and Dalton minima.

But in 2020 Cycle 25 actually had 80 per cent more sunspots overall than the equivalent period for Cycle 24, suggesting that the current cycle may in fact be stronger, rather than weaker. The international Solar Cycle 25 Prediction Panel said in September 2020 that they expect Cycle 25 to be about as strong as Cycle 24. Has the consensus changed since then, or is it still the same?

"The consensus has not changed," says panel co-chair Dr Doug Biesecker. The consensus is still that the current cycle will be much like Cycle 24. "We have not seen anything that differs significantly in the early stages of this cycle that varies from the panel prediction of a peak of 115 [sunspots] in July 2025." The predictions are based on the 13-month 'smoothed sunspot number' – a statistical method for calculating sunspots. And you have to be patient when studying the Sun. As Biesecker says: "It can take up to three years after the cycle begins before we can say with confidence whether the prediction is still valid."

Successfully predicting solar weather is certainly essential when testing scientific theories about how the Sun works. But there's a more pressing practical reason for doing so. Strong solar flare events and coronal mass ejections – most likely to occur around the time of solar maxima – can disrupt modern technology.

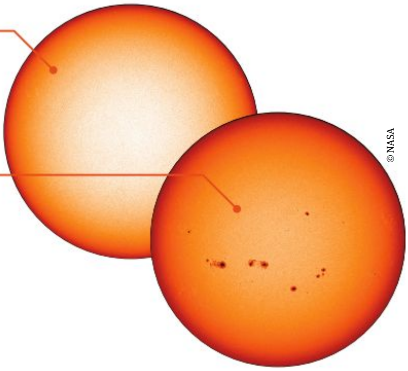
The flux of high-energy particles can damage spacecraft, satellites and even ground-based power systems. The latter are particularly vulnerable, as solar radiation easily disturbs Earth's magnetic field, inducing currents in long power lines. Such a geomagnetic storm destroyed large grid transformers and shut down the whole of Quebec, Canada, in March 1989. And this was just history repeating itself. In September 1859 a geomagnetic storm, dubbed the Carrington event, caused interesting problems with the telegraph system.

Telegraph operators noticed that they could disconnect their batteries and work with just the induced currents from the storm – sometimes with improved results! To this day it is the most powerful coronal mass ejection on record. If a Carrington-level event were to happen now, it would cause widespread damage and disruption to power systems and satellites. As well as decimating electronics, any astronauts venturing beyond the protective blanket of Earth's geomagnetic field – such as to the Moon or Mars – would be in danger, something that NASA's upcoming Artemis lunar program needs to keep in mind.

Considering the stakes, coupled with the fact that the Sun is such a complex system, there must

WHAT IS A SOLAR MAXIMUM AND SOLAR MINIMUM?

Solar maxima and minima happen some years apart, though at regular but varied intervals



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SOLAR MINIMUM

The period within the 11-year solar cycle with the least activity. Very few solar flares and few – if any – sunspots are observed.

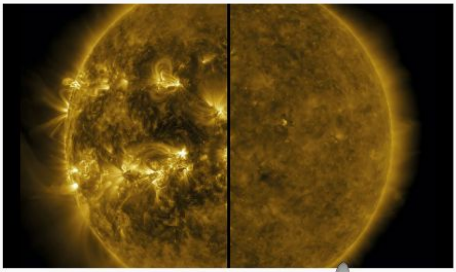
SOLAR MAXIMUM

The most active point in the solar cycle. Solar flares will manifest, as well as hundreds of individual sunspots, due to concentrated magnetic flux lines.

Below (clockwise from left): An active region with prominent magnetic loops, often visible during solar maxima

An active Sun at solar maximum (left) versus the Sun at solar minimum (right)

The Solar Dynamics Observatory studies many of the Sun's processes



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A DECADE OF THE SUN, FROM NASA

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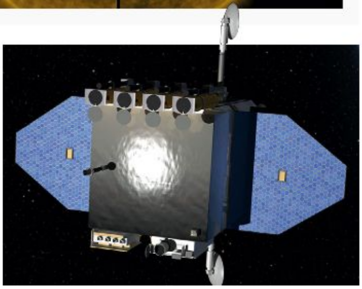

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be another way to glean information about its future behaviour besides sunspots. Other tried-and-trusted methods exist, but there may well be another arrow in the quiver. A US-UK team led by Dr Scott McIntosh of the High Altitude Observatory at the National Center for Atmospheric Research in Boulder, Colorado, has looked at a related phenomenon to sunspot activity.

Using data from sources such as NASA's Solar Dynamics Observatory, the team looked at extreme ultraviolet and X-ray flashes in the solar corona. These so-called 'bright points' in the Sun's atmosphere correlate with large areas of material flowing in the Sun's interior, which rotates faster than surface plasma, similar to rates seen for sunspots. Dr Robert Leamon of the University of Maryland likens it to helium balloons being dragged along by weights attached to the bottom.

Such a study is potentially more useful than the sunspot cycle as it shows magnetic polarity. In the 19th century, Richard Carrington and Spörer both discovered sunspots appearing at different latitudes during different points in the solar cycle, starting at mid-latitudes and migrating towards the equator at the end. Plotted against time, this leads to a distinctive 'butterfly' diagram.

But in the early 20th century, American astronomer George Ellery Hale proved the importance of solar magnetism by showing how a complete polar flip actually spans two sunspot cycles: a flip, then a flip back. This 22-year Hale cycle is what McIntosh's team looks at. The bright points are markers of Hale cycle magnetic bands.

This begs the question of why the wider solar scientific community doesn't make more use of such observations in this way. "Folks have in the past – calling them ephemeral active regions – but predominantly they are locked into the 'big white whales' of solar activity: sunspots," says McIntosh. Just like sunspots, the magnetic bands travel the latitudes of the Sun to meet at the equator, annihilating in what McIntosh calls 'termination events'. His team uses these termination events to identify complete 22-year magnetic cycles, as well as the 11-year sunspot cycles of the past.

Using these alongside predictions made for a 2020 terminator event, the team predicts that Solar Cycle 25 will, in fact, be strong. In marked contrast to scientific consensus, they say it will be among the strongest few ever recorded.

Source: Wikipedia Commons © Luc.rouppe

DETAILED PICTURE OF SOLAR SURFACE WITH ANTON PETROV

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Above: Close-up view of a sunspot. Counting sunspots is the staple way of measuring solar activity

HOW ARE SUNSPOTS MADE?

Sunspots are a consequence of the Sun's magnetic field and complex fluid dynamics

1 STRAIGHT MAGNETIC FIELD LINES, FEW SUNSPOTS

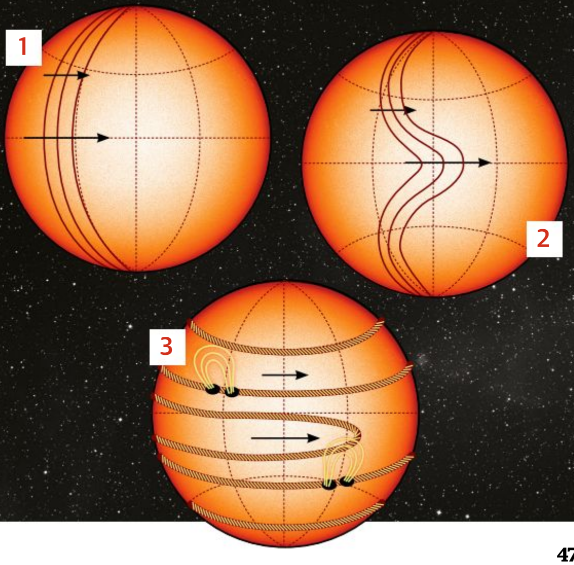
The Sun's global magnetic field lines start off straight, meaning few – if any – sunspots are visible. This occurs during, or close to, solar minimum.

2 FIELD LINES START TO BECOME DISTORTED

The Sun is not a solid body like Earth, composed instead from a fluid plasma. Its equator rotates faster than its poles, dragging field lines with it.

3 TWISTED TANGLES BREAK THE SURFACE

As the global field wraps around the Sun, concentrated magnetic loops break the surface, forming sunspots. These start at high latitudes.



> "THE SUN REALLY WANTS TO BE BALANCED, AND WHAT WE SEE IN TERMS OF SUNSPOTS IS THE RESULT OF IMBALANCE IN THAT PRESSURE"
>
> SCOTT MCINTOSH

OUR SUN

What goes on inside the mysterious powerhouse that dominates our Solar System?

SOLAR CORE

1 The Sun's thermonuclear fusion heart spans 27 times Earth's diameter. This is where hydrogen is fused into helium at huge temperatures and pressures, releasing energy.

RADIATIVE ZONE

2 Extending from the core to 70 per cent of the Sun's radius, energy propagates outwards via heat conduction and diffusion of electromagnetic radiation.

CONVECTION ZONE

3 Extending to just below the surface, the solar plasma's density reduces enough that material can move in a fluid way via convection currents.

PHOTOSPHERE

4 The Sun's visible surface is composed of convective cells, the upwellings and downfalls of the convection zone below. This gives the Sun its distinctive granular look.

CHROMOSPHERE

5 The Sun's thin lower atmosphere sits above the photosphere and extends to 3,000 to 5,000 kilometres (1,864 to 3,107 miles) above. Its deep-pink colour is visible during a total solar eclipse.

PROMINENCE

6 Hot plasma emanating from the photosphere, typically extending thousands of kilometres. Their structure comes from loops of magnetic field lines.

SUNSPOTS

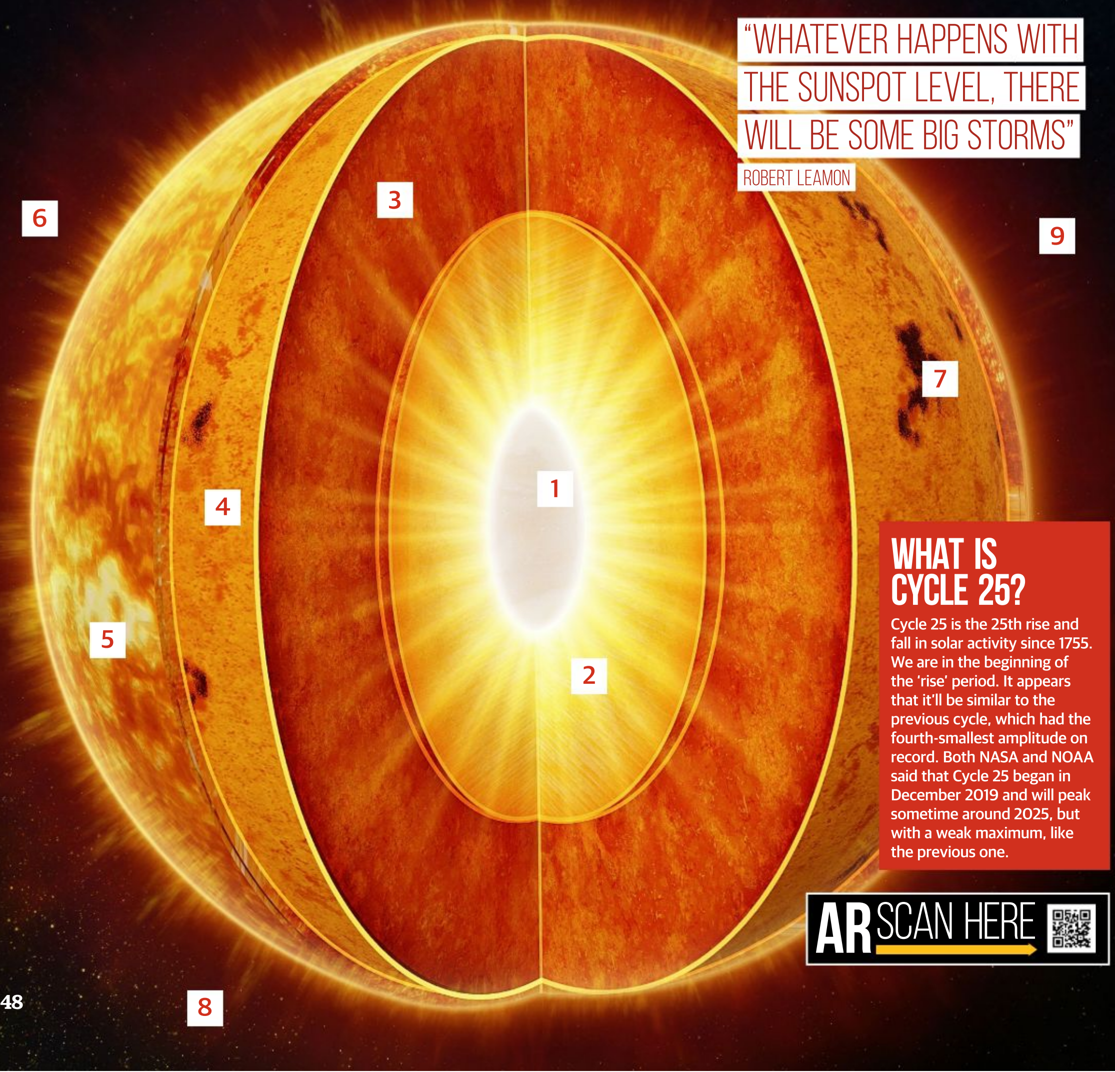
7 Concentrated magnetic fields inhibit convection wherever they punch through the surface. This reduces the temperature at those points, leading to relative darkening.

CORONAL HOLE

8 A sparse area of the Sun's upper atmosphere, the corona. Unfettered by any strong magnetic fields, solar particles stream out at twice the average rate.

CORONAL STREAMER

9 These bright magnetic loops of charged particles only tend to form at mid-latitudes. The solar wind stretches them into the coronal region.



> "WHATEVER HAPPENS WITH THE SUNSPOT LEVEL, THERE WILL BE SOME BIG STORMS"
>
> ROBERT LEAMON

WHAT IS CYCLE 25?

Cycle 25 is the 25th rise and fall in solar activity since 1755. We are in the beginning of the 'rise' period. It appears that it'll be similar to the previous cycle, which had the fourth-smallest amplitude on record. Both NASA and NOAA said that Cycle 25 began in December 2019 and will peak sometime around 2025, but with a weak maximum, like the previous one.

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Biesecker is supportive of the team's approach: "The work from McIntosh et al is very intriguing. It would be very exciting to have their prediction come true, as it would help teach us about how to better predict future solar cycles." But he does have a caveat. "The McIntosh technique has yet to make a true prediction. That is, one for which there is no knowledge of the future. It's very difficult for a panel to give much weight to a technique that is new, which has never made a prediction that can be tested." He says other more traditional methods continue to be used, as they have been successful in the past and are better known.

If McIntosh's study is right, however, what could it say about the solar interior? "That the magnetic systems inside the Sun are much stronger than we anticipate and that they interact strongly to shape the production of spots," says McIntosh. He says the pressure of the magnetic field band relative to the surroundings is important. "My sense is that the Sun really wants to be balanced, and what we see in terms of sunspots is the result of imbalance in that pressure – globally, locally and longitudinally." This means they think they're only seeing the tip of the iceberg where the magnetic field is concerned.

McIntosh goes on to say that the recurrence of 55 degree latitude bands in their analysis, which can be traced back through the entire observational and photographic record, is very overlooked. It suggests structural or geometric features that play a significant role in forming and aggregating the magnetic field in the Sun's interior.

The science still has many open questions. But is the team's approach bearing out for space weather forecasting? As Leamon says: "It's too early to tell, but so far the observed sunspot number and other measures, such as F10.7 solar radio flux [10.7 centimetre-wavelength radio waves] are tracking closer to our higher predictions rather than the lower panel consensus. Whatever happens with the sunspot level, there will be some big storms, and our technological society will be impacted in some way or another during Solar Cycle 25."

McIntosh concurs: "Indications are that it's on track to be bigger than 24, and likely 23 too. But we really need the termination event to happen to get real fidelity on the forecast." He's still convinced that it'll be a larger-than-average cycle, perhaps even in the top ten of every one on record. "But until that event happens, we won't know for sure."

Biesecker's looking further ahead. "The relevance of the Hale cycle, as detailed in McIntosh et al, will be something for the Solar Cycle 26 Panel to consider." He points out that looking at the 22-year Hale cycle isn't new to forecasting, and that scientists have looked at the effects of odd and even cycles in the past, although with less skill than looking at precursors of the next immediate cycle. "Expect the McIntosh technique to be a big part of the conversation when the panel to forecast Solar Cycle 26 convenes," he tantalisingly concludes.

Kulvinder Singh Chadha
Space science writer
Kulvinder is a freelance science writer, outreach worker and former assistant editor of *Astronomy Now*. He holds a degree in astrophysics.

ON CYCLE 25

Solar scientist Madhulika Guhathakurta gives her personal view of our current solar cycle

DR MADHULIKA GUHATHAKURTA

A heliophysicist at NASA and leader of the Living with a Star Program. She started International Living with a Star in 2003. Presently on part-time detail at Goddard as senior advisor for new initiatives.

Guhathakurta gives her opinion as an individual and not as a representative of any organisation.

How unusual is Solar Cycle 25's sunspot activity?

Looking at sunspots as a non-physical index of solar activity, I think this solar cycle isn't unusual, especially in the context of the prior cycle. This cycle's sort of mimicking that. Even in the early 1800s and 1900s, you see cycles of this magnitude. During the Maunder minimum, when we couldn't detect any sunspots, the question remains how well could we detect very faint sunspots then or even now? We don't know and have no measure of that. The uncertainty associated with detecting no sunspots is much harder than counting them during solar maximum.

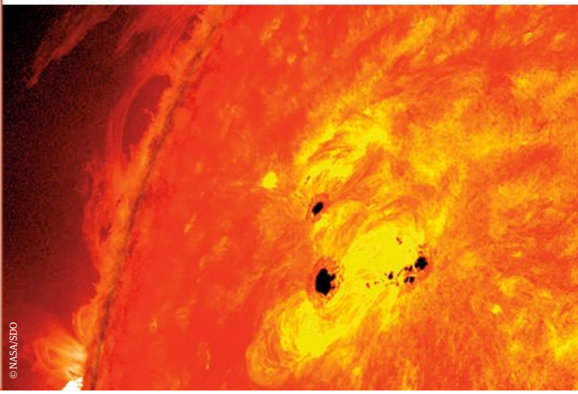
How does Cycle 25 fit with current knowledge?

Our present understanding is Babcock's solar dynamo model. Even though the details aren't well understood, it describes why we see what we see in terms of magnetic field activity, including the 11-year sunspot cycle. Inside the Sun, closed field magnetic loops are generated in the equatorial region, but open field lines at the poles in the corona become more dominant during solar minimum. Solar physicists agree that polar fields during solar minima dictate the strength of the next solar cycle. We can't measure polar field strength accurately, as we have to go outside the ecliptic plane. The Solar Orbiter mission from the European Space Agency, partnered with NASA, will give us a better estimate.

Are you seeing longer term trends?

The importance of these hasn't received proper scrutiny for lack of data. Beyond that I don't think we have a deeper understanding of the physics – there are many layers to go through. I spent the last four years at NASA Ames Research Center shaping a program called Frontier Development Lab and got fascinated by artificial intelligence and how we might utilise our data and the tools of AI to infer patterns that can better guide physics outcomes. Machine learning and AI could be critical for understanding solar variability and climate with huge amounts of data.

Below: Sunspots appear as dark patches on the tumultuous surface in this image taken by the Solar Dynamics Observatory



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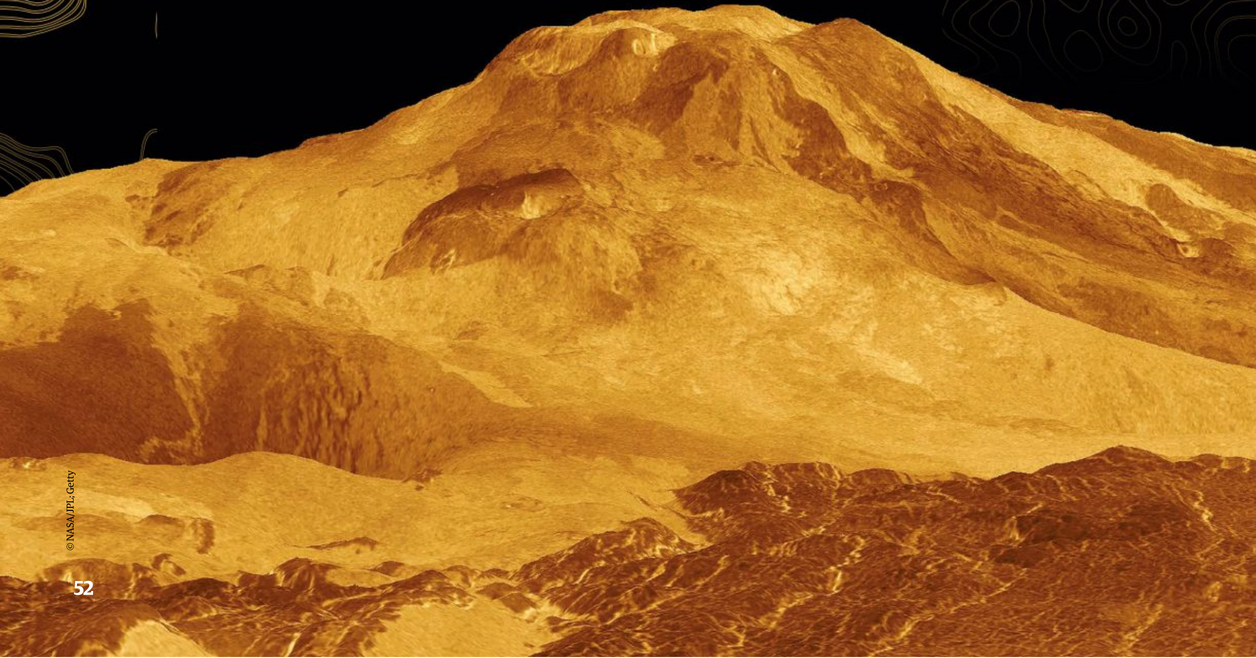
10 AMAZING VOLCANOES IN THE SOLAR SYSTEM

Explore these violent openings into the inner workings and origins of the planets and their moons

Reported by James Romero



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Every time we have visited a new world in our Solar System we have been surprised. While century-old predictions of Venusian rainforests or canal-building Martian civilisations proved off the mark, the age of space exploration has revealed life, in a geological sense, is ubiquitous. Volcanism, the upwelling and outpouring of inner planetary material, whether water, rock or mud, appears to be a fundamental process shaping every solid body we have visited.

For this volcanic tour, we not only travel from the inner to the outer Solar System, but also dive into the interior of planets and moons. Volcanoes are windows into the inner workings of Solar System worlds, revealing the story of their formation and signalling what their future might hold. And when that interior contains potentially habitable oceans, as are thought to exist within a few of our icy moons, volcanism might even provide the first signs of life on – or rather inside – another world.

MAAT MONS

LOCATION: VENUS

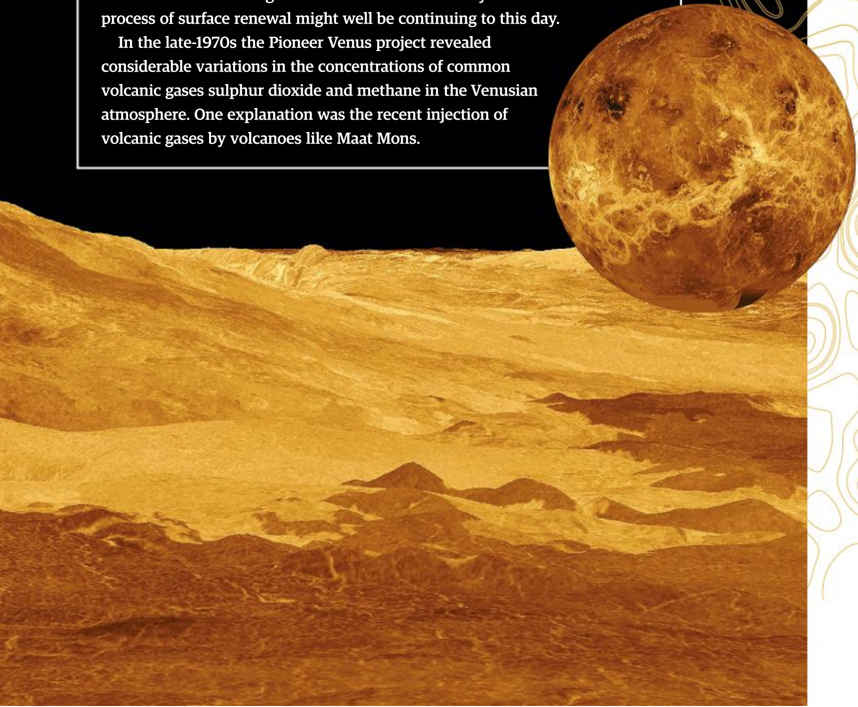
HEIGHT: EIGHT KILOMETRES (FIVE MILES)

ACTIVE: MAYBE

The highest volcano on the Venusian surface, Maat Mons confounded expectations. It was thought the surface pressure on Venus would prevent the formation of such steep-sided slopes. However, recent models suggest that a sufficiently viscous Venusian lava can explain Maat Mons, as well as other cone-shaped formations. In fact, the surface pressure may contribute to their formation, stopping erupted material dispersing too far from the vent.

However you explain Maat Mons, Venusian volcanoes like it have certainly left their mark across the planet's surface, which as a result of extensive recent lava flows averages out at a mere 750 million years old. And that process of surface renewal might well be continuing to this day.

In the late-1970s the Pioneer Venus project revealed considerable variations in the concentrations of common volcanic gases sulphur dioxide and methane in the Venusian atmosphere. One explanation was the recent injection of volcanic gases by volcanoes like Maat Mons.



AHUNA MONS

LOCATION: CERES

HEIGHT: FOUR KILOMETRES (2.5 MILES)

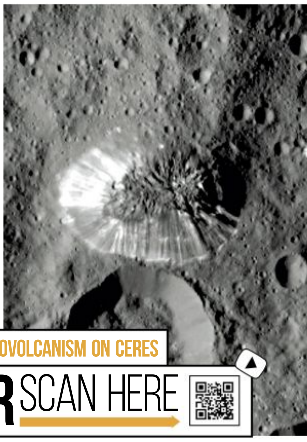
ACTIVE: YES

Volcanism can even be found within the asteroid belt. And on Ceres, the largest object found orbiting between Mars and Jupiter, it takes an odd form.

In 2015, among a surface of cratered but relatively flat terrain, the Dawn spacecraft imaged Ahuna Mons, a 17-kilometre (10.5-mile) long, flat-topped, oblong mountain. With no signs of plate tectonics on Ceres, Ahuna's origin was pinned on an upwelling beneath the crust, possibly the closest example of cryovolcanism in the Solar System.

However, the lavas here were not the almost-pure-water outpourings found on the surface of Jovian and Saturnian moons. The viscous relaxation and the mineralogy of the dome suggested these magmas contain a lot of suspended rocky material, and Ahuna Mons was labelled a mud volcano.

Simulations predict it is fed by a plume extending from the mantle to the dome above it, raising the possibility that Ceres' mantle is still churning, pushing material up into Ahuna Mons and making it grow.



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CRYOVOLCANISM ON CERES

AR SCAN HERE

MARIUS HILLS

LOCATION: THE MOON

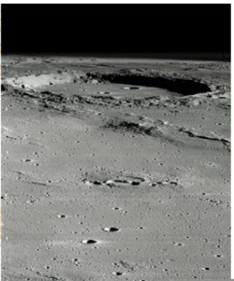
HEIGHT: 200-500 METRES (650-1,640 FEET)

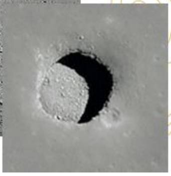
ACTIVE: NO

The Marius Hills are the largest volcanic dome field on the Moon, containing numerous domes up to 500 metres (1,640 feet) tall. The region is also home to the Marius Hills Hole, a several-hundred-metre-wide opening of the lunar surface that provides an 80-metre (262-foot) high window into what scientists think is an ancient lunar lava tube. Some engineers have even considered the hole's natural shielding as a prime location for a future lunar base.

Up until the time astronauts returned Moon rocks for analysis, there was a debate about whether our celestial companion was ever a volcanic world. Only once the Moon rocks were analysed on Earth was it confirmed the big, dark mare, or seas, weren't impact craters, as some had suggested, but ancient lava flows.

While the volcanism that once produced the Marius Hills is long gone, there are places on the lunar surface where volcanism could have been taking place in the last few hundred million years. And if that can be proved, it isn't implausible we will see lunar eruptions again in the near future.





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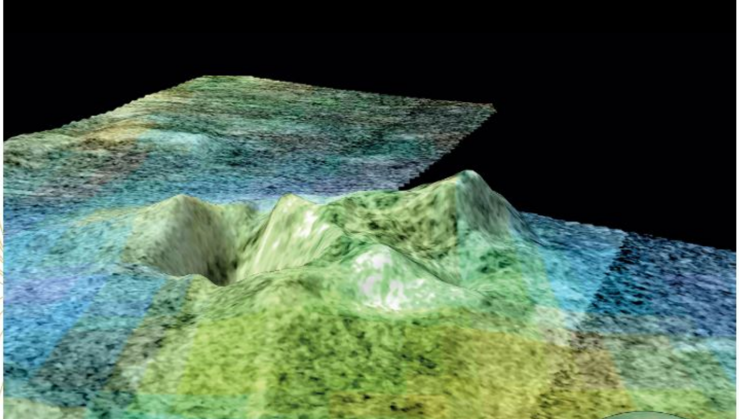

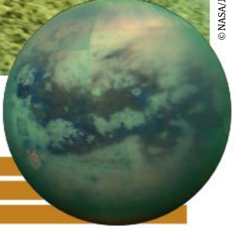

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DOOM MONS

LOCATION: TITAN

HEIGHT: 1.45 KILOMETRES (0.9 MILES)

ACTIVE: PROBABLY

Doom is the highest point of a southern hemisphere mountain range. It is thought to have grown through cryovolcanism, the steady oozing of molten water and methane ice from cracks in the crust. Mohini Fluctus, a bright lobe-shaped flow at least 200 kilometres (124 miles) long, appears to emerge from the mountain and extends to the northeast. Like everywhere across Titan's surface, Doom Mons is constantly bombarded with various elements of the moon's orange-tinged atmosphere. These include wind, rain and snow particles composed of liquid methane and ethane, as well as hydrocarbon smog and haze. This bombardment means the volcano's structure is constantly changing, while wind erosion may also play a role in limiting the height of its peak.

MOUNT ETNA

LOCATION: EARTH

HEIGHT: 3,350 METRES (11,000 FEET)

ACTIVE: YES

One of the most famous and active of Earth's classical conical-shaped volcanoes, Italy's Mount Etna is a testament to Earth's seemingly unique system of plate tectonics. This process is fuelled by interior radioactive elements, which at the surface drive the constant pushing and diverging of a patchwork of oceanic and continental plates.

It is on top of one of these convergent plate boundaries that Mount Etna sits, spewing out molten rock melted far below by the subduction of the water-rich African Plate underneath the Eurasian Plate. It is the introduction of water and other gas-forming volatiles into the subsurface that creates more viscous magmas, resulting in a unique type of explosive volcanism on Earth. Plate tectonics are a fundamental mechanism of our planet, recycling vital minerals for life between the surface and subsurface.

HAWAIIAN COLOSSUS

Earth's tallest mountain is a volcanic island. Mauna Kea is a mile taller than Everest.

ERUPTIONS ON MOUNT ETNA

AR SCAN HERE

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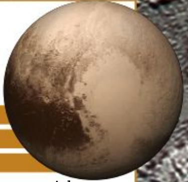
WRIGHT MONS



LOCATION: PLUTO

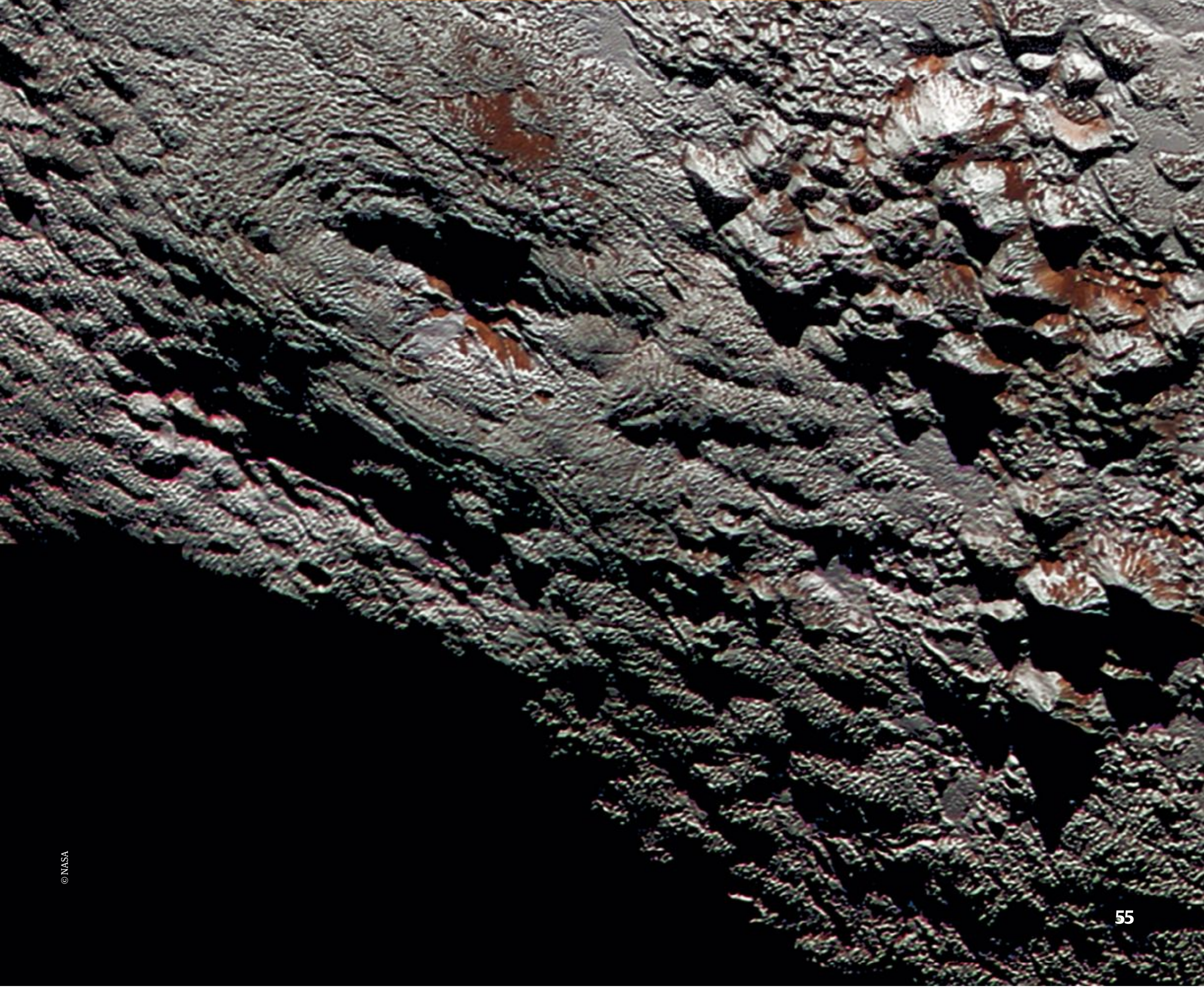
HEIGHT: FOUR KILOMETRES (2.5 MILES)

ACTIVE: YES

While Saturn and Jupiter's moons confounded expectations that the outer Solar System might provide slim pickings for volcano hunters, few held out hope of further riches when New Horizons arrived at Pluto in 2015. However, it seems geology found a way even within the frigid backwaters of the Kuiper Belt.

The telltale sign came from a surprisingly smooth terrain. Scientists could only identify one impact crater on Wright Mons itself, indicating that the surface – as well as some of the crust underneath – was created relatively recently. This in turn may indicate that Wright Mons was volcanically active late in Pluto's history. The cryolavas used to explain the landscape consist of water, ammonia and a coloured component thought to be complex organic matter. The presence of ammonia appears key to the mystery, as it can act like antifreeze to melt frozen ice, and its susceptibility to destruction through ultraviolet light exposure further supports the idea of recent volcanic activity.

As with Europa and Enceladus, volcanism on Pluto provides a tantalising window to what could be an ammonia-rich water ocean beneath the icy crust.



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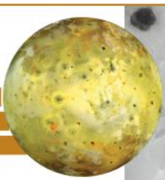
LOKI PATERA



LOCATION: IO

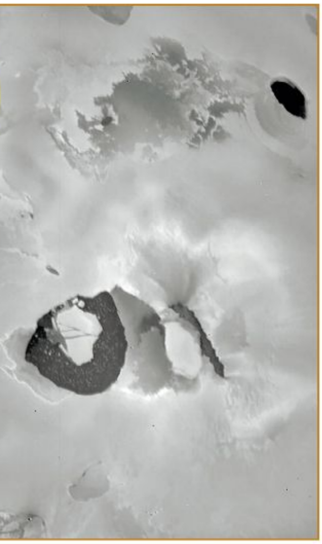
HEIGHT: 0 KILOMETRES (0 MILES)

ACTIVE: YES

Prior to the launch of the Voyager spacecraft, few expected to find active volcanism out among the freezing parts of the Solar System. One exception was a team led by American planetary scientist Stan Peale. Peale's prophetic paper three months before Voyager 1's arrival at Jupiter predicted the combined orbital forces of the gas giant and its other moons could sufficiently squeeze tiny Io, melting its interior.

However, even Peale couldn't have envisioned what Voyager 1 saw as it flew by. More than 400 active volcanoes make Io the most violent geological world in the Solar System.

Loki is the largest of Io's plume-spouting volcanoes. A 201-kilometre (125-mile) wide volcanic lake, it erupts at regular intervals, approximately every 540 Earth days. These eruptions release 400-kilometre (250-mile) tall jets that distribute sulphur and sulphur dioxide widely across vast areas of the surface.



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THE TIGER STRIPES

LOCATION: ENCELADUS

HEIGHT: 0 METRES (0 FEET)

ACTIVE: YES

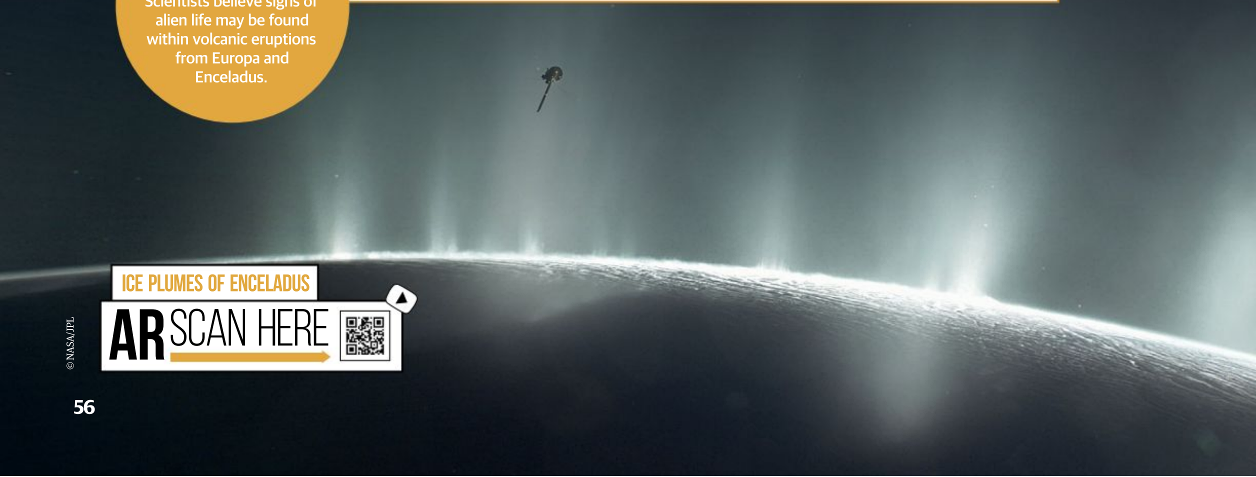
Few worlds' volcanic natures have caused such shock, excitement and awe as that of Saturn's tiny moon Enceladus. In March 2006 the Cassini spacecraft imaged large icy jets emanating from the moon's 'tiger stripes', a series of cracks that dominate its south polar region. A vast chain of geysers constantly erupt from the stripes, sending huge amounts of watery materials into orbit around the moon's host gas giant and feeding Saturn's E-ring.

Cassini subsequently flew through an erupting plume, identifying a water-ice composition with traces of carbon dioxide, ammonia, methane and other complex hydrocarbons. It is these contaminants that lower the melting temperature of the icy Enceladus crust, supporting the generation of these cryomagmas.

The presence of complex hydrocarbons in the erupted vapours point to a subsurface ocean, and perhaps the type of hydrothermal vent chemistry that on Earth supports rich ecosystems on our ocean floors.

ALIEN ERUPTIONS

Scientists believe signs of alien life may be found within volcanic eruptions from Europa and Enceladus.



ICE PLUMES OF ENCELADUS

AR SCAN HERE

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EUROPA'S CRYOGEYSERS

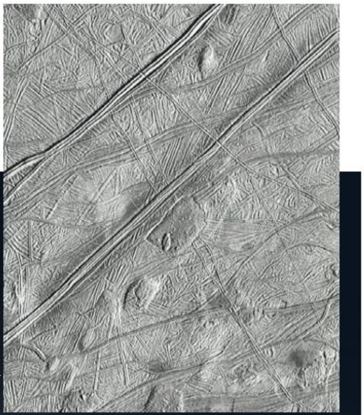
LOCATION: EUROPA

HEIGHT: UP TO 100 METRES (328 FEET)

ACTIVE: YES

Outer Solar System volcanism can take strange forms. In 2012 Hubble detected water vapour plumes from the south pole of the Jovian moon Europa. These were later linked to circular domes on the surface, thought to be erupting cryogeysers. The Hubble images suggested the plumes may be 200 kilometres (124 miles) high. What is less clear is how water, which uniquely becomes denser when it melts, can rise from the interior and flow out on the surface.

Europa has long fascinated scientists due to predictions of a subsurface ocean. Flyby sampling of these volcanic plumes could help astronomers search for life within this ice-capped ocean without having to drill through the frozen surface.



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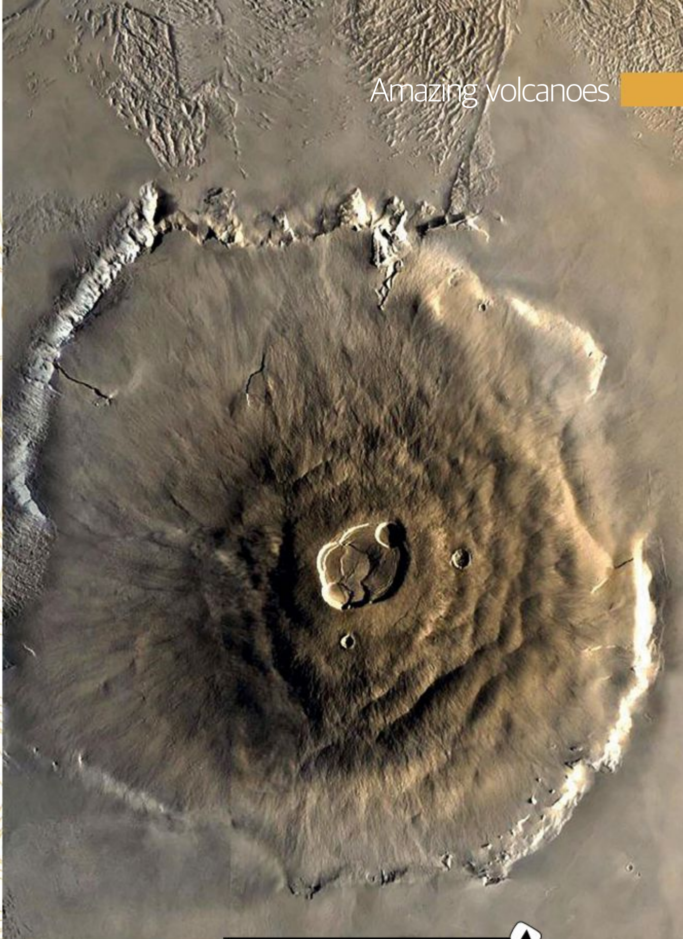

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TRACES OF LIFE ON MARS: OLYMPUS MONS

AR SCAN HERE

OLYMPUS MONS

LOCATION: MARS

HEIGHT: 21 KILOMETRES (13 MILES)

ACTIVE: MAYBE

The largest volcano in the Solar System, Mars' Olympus Mons stretches over an area equal in size to the state of Arizona. It's so big that if someone dropped you in the summit's caldera crater, you wouldn't be able to see the crater rim, which would lie beyond the horizon. Its weight flexes the Martian lithosphere, which bends beneath it like a bowling ball on a trampoline.

A shield volcano, Olympus Mons is formed by pulses of magma coming up in a column, known as a plume. This may extend all the way down to the core-mantle boundary thousands of kilometres below. If Mars had plate tectonics like Earth, successive pulses from such a plume would create island chains like Hawaii as the plate moved over this superheated column. However, Mars, like Venus and Mercury, has no such process. As a result, for billions of years the Olympus Mons plume has produced relatively gentle lava flows from a single spot, each one pouring out on top of the last, steadily adding to its gently inclined topography.

The youngest lava flows on the northwestern flank of Olympus Mons have been dated as young as 2 million years old. These are very recent in geological terms, suggesting that the mountain may still be active, though in a very quiescent and episodic fashion.

THE VOLCANIC GIANT

During a dust storm on Mars in 1971, Mariner 9 could still see Olympus Mons above the clouds.

FOUND! SAFEST PLACE TO LIVE IN THE MILKY WAY

Astronomers have searched our galaxy to identify the safest places to live. As it turns out, we're in a pretty good spot

Reported by Mara Johnson-Groh

© ESO

If the past year has made you feel ready to relocate to another planet, you might want to look towards the centre of the galaxy. The new findings were made by a group of Italian astronomers, who studied locations where powerful cosmic explosions may have killed off life. These explosions, such as supernovae and gamma-ray bursts, spew high-energy particles and radiation that can shred DNA and kill life. By this logic, regions that are more hospitable to life will be the ones without frequent explosions, the astronomers reasoned.

"Powerful cosmic explosions are not negligible for the existence of life in our galaxy throughout its cosmic history," said Riccardo Spinelli, an astronomer at the University of Insubria in Italy. "These events have played a role in jeopardising life across most of the Milky Way."

In addition to finding the deadliest hotspots, the astronomers also identified the safest places throughout the galaxy's history, going back 11 billion years. The results show that we're currently at the edge of a wide band of hospitable real estate. But in the Milky Way's youth, the galaxy's edges were a safer bet.

Many factors make a planet habitable. For instance, planets need to be in a 'Goldilocks zone', where heat and activity from their host star isn't too much or too little… it's just right. But in addition to these local conditions, life also has to combat harmful radiation coming from interstellar space.

Powerful cosmic events like stellar explosions stream dangerous, high-energy particles at nearly the speed of light. Not only can they kill all the life forms we know about, but these particles can also strip entire planets of their atmospheres. After such an event, the scientists

“FOR PLANETS CLOSE TO THE STELLAR EXPLOSION, IT’S PLAUSIBLE THAT THERE IS A COMPLETE STERILISATION”

RICCARDO SPINELLI

believe that planets orbiting nearby star systems would be wiped clear of life.

“For planets close to the stellar explosion, it’s plausible that there is a complete sterilisation,” Spinelli said. “In those far away, a mass extinction is more likely.” A nearby gamma-ray burst may have played a leading role in the Late Ordovician mass extinction event around 450 million years ago – the second largest in Earth’s history. While there is no concrete evidence linking a specific gamma-ray burst to this extinction event, the study authors think it could be likely, given Earth’s position in the galaxy.

Using models of star formation and evolution, the astronomers calculated when specific regions of the galaxy would have been inundated with killer radiation. Early on in our galaxy’s history, the inner galaxy out to about 33,000 light years was alight with intense star formation, which rendered it inhospitable. At this time, the galaxy was frequently rocked by powerful cosmic explosions, but the outermost regions, which had fewer stars, were mostly spared these cataclysms.

Until about 6 billion years ago, most of the galaxy was regularly sterilised by massive explosions. As the galaxy aged, such explosions became less common. Today the mid-regions, forming a ring from 6,500 light years from the galaxy’s centre to around 26,000 light years from the centre, are the safest areas for life. Closer to the centre, supernovae and other events are still common, and in the outskirts there are fewer terrestrial planets and more gamma-ray bursts.

Luckily for us, our galactic neighbourhood is getting more and more life-friendly. In the long-term galactic future, there will be fewer extreme events nearby that could cause another mass extinction from space.

HOW TO SPOT A FAKE SPACE PHOTO

REVEAL IF THAT SENSATIONAL IMAGE IS REAL OR A FRAUD WITH ALL ABOUT SPACE'S TOP TIPS

Written by Stuart Atkinson

If you use any social media platforms you will know they are dominated by two types of images: pictures of cute cats, and photographs of anything to do with space. Every platform has thousands of members who enthusiastically share photographs taken through the International Space Station's windows, by space probes on or orbiting planets and through telescopes. Many are jaw-droppingly beautiful, and during the past difficult year every time a photo of the northern lights blazing above snow-capped Canadian mountains or a view of a copper-hued eclipsed Moon hanging above a city skyline has popped up on our timelines, it's not just been a pleasant surprise, but a welcome distraction from our everyday troubles. If there was a cat in it too, even better...

Unfortunately, many of the beautiful astronomical images posted on Facebook, Twitter or Instagram are not what they claim to be. Some are genuine, but stolen from other people. Others are composites, impressive but totally fake combinations of several different genuine photos to make something inaccurate or scientifically impossible. Others still are purely digital creations, produced inside computers with not a camera in sight. Why do people create, or knowingly share, these fake images? What do they get out of it?

It has to be said that some do it simply to fool people, to deliberately cause trouble and wind people up. They post their fake images then sit back and wait for the angry responses to come in from people who have spotted their fakery, and they get a good laugh out of it. Others are attention seekers who want to be popular on social media; they want as many likes or shares as possible. A few do it because they don't have the equipment, experience or skill needed to create genuine images, or they do but they are too lazy to learn how to take them themselves, so they create fake images or steal other people's and claim them as their own, usually after 'tweaking' them in some way in the hope people won't notice.

Others are looking for financial reward: the media loves jaw-dropping images of eclipses, a bright shooting star or a display of the northern lights, and sometimes will pay for them. Unfortunately, many of the people who select images for use in newspapers and for their websites have very little - if any - astronomical knowledge, so they don't know which images are real and which are fake. Some of them probably don't care - as long as an image is colourful and dramatic they'll use it, hoping to attract more readers. Before we look at how to spot these fakes and prevent yourself from being fooled - and maybe even unwittingly spreading them more widely across the internet - let's take a look to see how this all started.

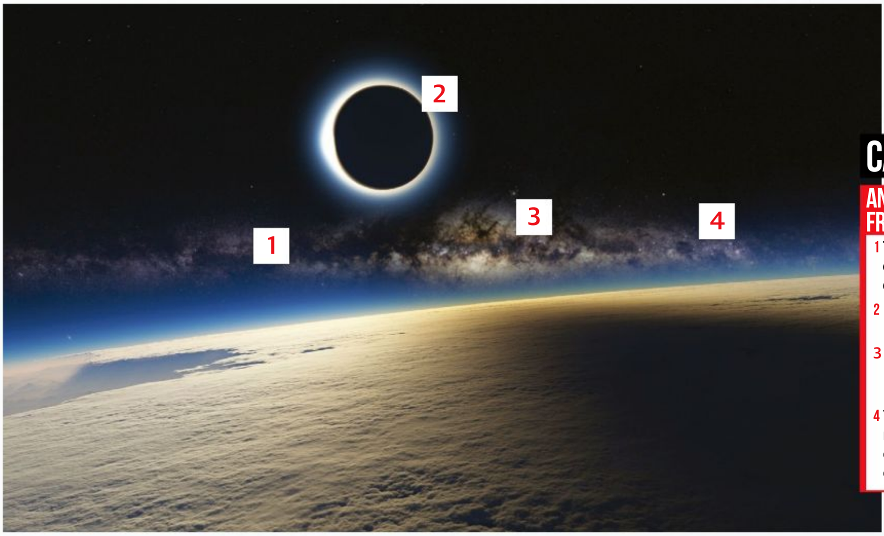
It used to be all but impossible to fake a 'space' image, especially astrophotographs of objects in the night sky. Decades ago, cameras held coiled-up strips of light-sensitive film, which had to be processed in tanks of chemicals to produce prints, or slides. Those images were essentially 'one-offs', printed in books and magazines and on posters, and couldn't be copied. Today sky-watchers are armed with digital cameras that would have been considered sorcery back in those days, routinely firing off dozens or even thousands of images in one night without the old worries about running out of film. The next morning we process and stack our images on our computers, then post them online for others to enjoy - where anyone can steal them with a click of a mouse or a tap of a finger and then either claim them as their own or use them to make another image.

> "MANY OF THE BEAUTIFUL ASTROIMAGES ARE NOT WHAT THEY CLAIM TO BE"

Today there are so many stolen or faked images out there you'd be forgiven for thinking that spotting one is like looking for a needle in a field of haystacks. In fact, once you know what to look for, it's quite easy to tell if an astroimage is fake or not.

First of all, you don't have to be a detective to think that it's a bit odd when someone posts a stunning wide-field image of the night sky without any previous references to taking such photos. Every expert astrophotographer working today took terrible photos when they started out, and the quality of their work gradually improved as they built up their skills.

If someone who has never posted even a simple constellation portrait before suddenly posts an amazingly detailed image of a galaxy or nebula, claiming it as their own, you could be forgiven for raising an eyebrow and wondering if they're passing off someone else's work as their own - and they often are. This kind of image theft happens a lot, but even though the offenders are quickly



CASE STUDY #1

AN ECLIPSE SEEN FROM THE ISS

1 This is a bad composite of several different images

2 The eclipsed Sun is too big in the sky

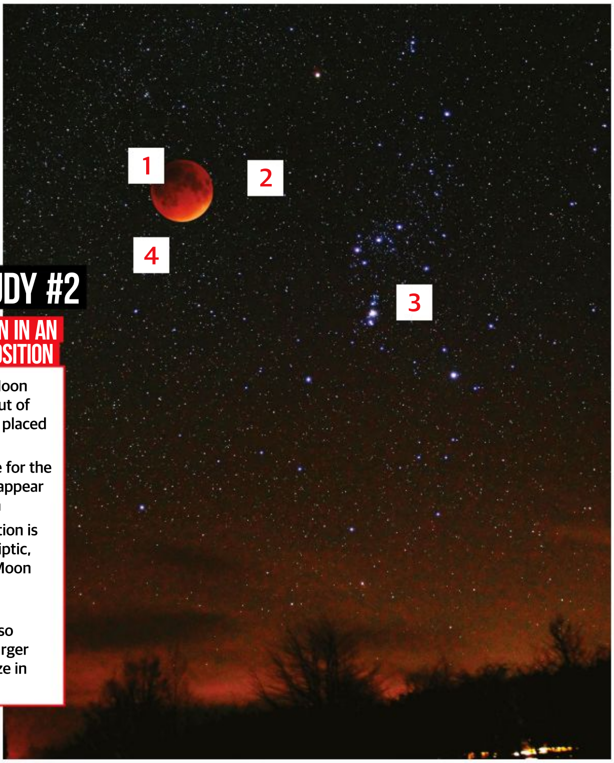
3 The Milky Way appears to be in front of the eclipse

4 The Milky Way would not be visible so clearly close to Earth, even in a dark sky

found out and named and shamed, it doesn't stop others doing it again and again.

Some images can be identified as fakes because they are astronomically inaccurate or simply impossible. It's so easy to Photoshop streaks of light onto a night sky image that after every meteor shower social media is flooded with photos claiming to show a sky full of brilliant shooting stars, except they are falling parallel to each other instead of radiating from a common point as they actually do. We've also lost count of the number of 'stunning images' people have shared showing the Milky Way blazing above a castle or beach somewhere at completely the wrong orientation to the horizon for that time of year, or looking ten times brighter and more detailed than it can ever appear in real life. Fakers who snip the Milky Way out of one image and blend it into another assume no one will know, but amateur astronomers can spot a fake image like that from light years away. However, people with no knowledge of the workings of the sky likely wouldn't spot anything suspicious, and they then share the images, genuinely believing they're real because they want to believe something so beautiful is real.

There are peak periods of fakery too. After every total lunar eclipse Twitter and Facebook groan under the weight of faked images showing the pumpkin-hued Moon glowing in a constellation it wasn't in - a sign that the 'photographer' actually made it by cutting an eclipsed Moon out of someone else's photo and then used image-



CASE STUDY #2

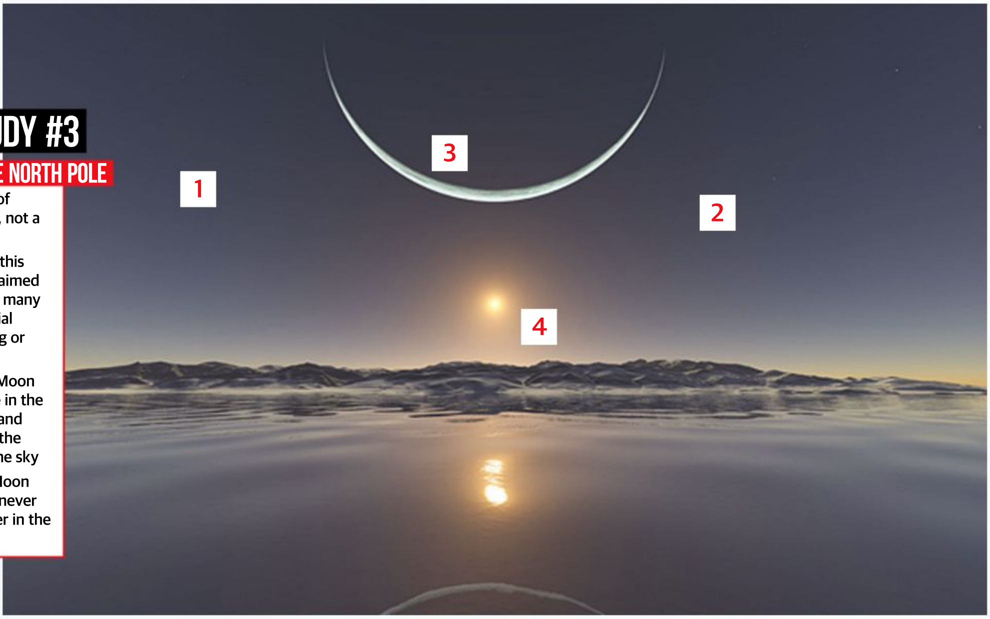
ECLIPSED MOON IN AN IMPOSSIBLE POSITION

1 The eclipsed Moon has been cut out of one image and placed over another

2 It is impossible for the Moon to ever appear in this position

3 This constellation is not on the ecliptic, the path the Moon follows across the sky

4 The Moon is also shown much larger than its true size in the sky



CASE STUDY #3

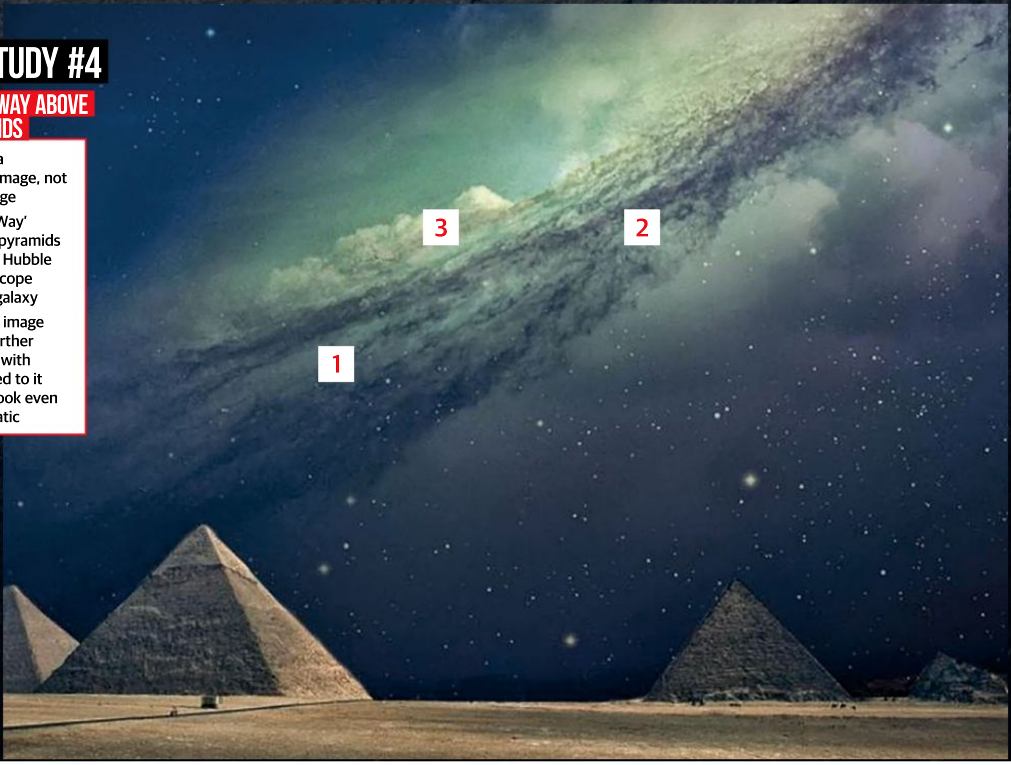
SUNSET AT THE NORTH POLE

1 This is a piece of digital artwork, not a real photo

2 The creator of this image never claimed it was real, but many share it on social media believing or claiming it is

3 The crescent Moon is far too large in the sky - the Sun and Moon appear the same size in the sky

4 The crescent Moon and Sun could never appear together in the sky like this



CASE STUDY #4

THE MILKY WAY ABOVE THE PYRAMIDS

1 This one is a composite image, not a single image

2 The 'Milky Way' behind the pyramids is actually a Hubble Space Telescope image of a galaxy

3 The Hubble image has been further 'enhanced', with clouds added to it to make it look even more dramatic

"SOME IMAGES CAN BE IDENTIFIED AS FAKES BECAUSE THEY ARE ASTRONOMICALLY INACCURATE OR SIMPLY IMPOSSIBLE"

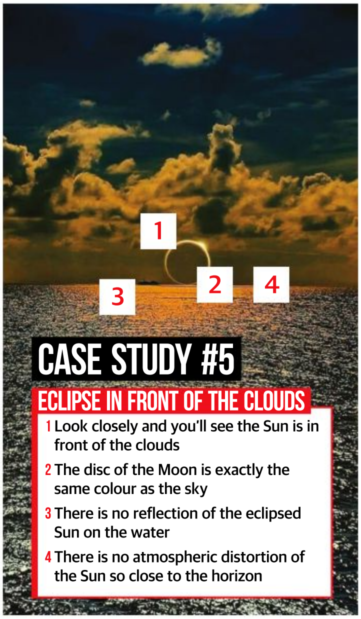
processing software to superimpose it onto another photo of a different star field altogether, usually a constellation nowhere near the ecliptic, the path the Moon follows across the sky.

Such 'composite' images are the most common type of fake. They require the least skill to make, but they are the most easily spotted. Giveaways of composites include being able to magically see stars through the Moon, spotting that the Moon's reflection in a lake or on the ocean doesn't line up with the actual Moon in the sky or seeing the Moon shining in front of clouds. Again all impossible things even a beginner to astronomy can tell are just wrong.

It's easy to spot another genre of fake astrophotos because they are simply ridiculous. One hugely popular image, shared after every solar eclipse, claims to have been taken from the International Space Station, showing an enormous eclipsed Sun shining above Earth with the Milky Way painted across the sky behind it. Another offender shows an eclipsed Sun with a blood-red corona surrounding it and an aeroplane flying in front of it, somehow fully illuminated.

Another problem non-astronomers have is knowing if the features and colours they see on a photo are accurate. Just like wedding and wildlife photographers, astrophotographers often 'tweak' their images a bit to add contrast and make details clearer, but some take it too far. This is particularly true for photos of the northern lights, which are often enhanced and saturated so aggressively that the subtle, natural pinks and greens of a display become splashes of bright crimson and neon green, giving a very false impression of what the displays actually look like.

After studying our parade of fake photos, you'll be able to spot the next that appears on social media and elsewhere - and avoid sharing these classics with the rest of the world.



CASE STUDY #5

ECLIPSE IN FRONT OF THE CLOUDS

1 Look closely and you'll see the Sun is in front of the clouds

2 The disc of the Moon is exactly the same colour as the sky

3 There is no reflection of the eclipsed Sun on the water

4 There is no atmospheric distortion of the Sun so close to the horizon

PLANET PROFILE
EARTH

The rocky world that we call home is full of wonders

A rather pretty blue-and-white planet orbiting an otherwise obscure G-type main sequence star, Earth is notable largely for being the only place in the universe to have evolved organic life. Other than this quirk of chemistry, the third planet from the Sun also has active plate tectonics, and it's one of the few planets whose moon fits perfectly over its Sun during an eclipse, leading to some fantastic sights. It is the densest planet in its Solar System, and the largest of the four rocky planets closest to its star. An atmosphere 100 kilometres (62 miles) thick coats the planet, offering it protection from ultraviolet light given out by its nearest star thanks to its layer of ozone. Heating of the upper atmosphere means it's slowly losing its hydrogen and helium into space, but at a very slow rate.

With its thick atmosphere and yellow sunlight, much of Earth's vegetation is green, though most of its inhabitants are not. Its position at around 150 million kilometres (93 million miles) from its star means liquid water is commonplace on its surface - both salty and non-salty forms, freezing at the poles - though a recent increase in atmospheric carbon dioxide levels is causing this ice to melt. Unlike its neighbour Mars, which is populated solely by robots, biological life flourishes both in Earth's oceans and on the third of the planet not covered with water.

An axial tilt of 23.5 degrees leads to seasons on the planet, which combine with both atmospheric and oceanic circulations to produce a variety of weather types, some of them extreme. A single, large natural satellite is tidally locked to the planet, and its gravitational pull affects the water level beneath it, causing tides. Along with the many artificial satellites created by its inhabitants, Earth also has a small number of quasi-satellites, mostly captured asteroids circulating around Lagrange points L4 and L5 in horseshoe orbits.

Earth is currently 20,000 years into an interglacial period, part of a cycle of ice ages that sees glaciers coat large parts of the planet over periods of up to 500,000 years. The current interglacial should end in around 25,000 years, though warming caused by increased atmospheric carbon dioxide levels could delay this by trapping heat within the atmosphere.

In a billion years' time, the energy received by Earth from its star will have increased by ten per cent, enough for the oceans to be lost thanks to a combination of subduction into the planet's mantle and photodissociation of the water molecules by increased levels of ultraviolet light. Without surface water, plate tectonics will come to a halt. Earth will become similar to its near-twin Venus, its neighbour on the sunward side, with a runaway greenhouse effect eventually raising the surface temperature to 1,330 degrees Celsius (2,426 degrees Fahrenheit).

In another 5 billion years, the Sun will run out of hydrogen to burn in its core and will begin the process of swelling into a red giant. As it expands, Earth, along with Venus and the small rocky planet Mercury, will be engulfed by its chromosphere. Tidal forces will break up the Moon, briefly turning it into a ring system before the surface and mantle are stripped from the Earth, leaving only its core. The final legacy of Earth will be an increase in the Sun's metal content of 0.01 per cent.

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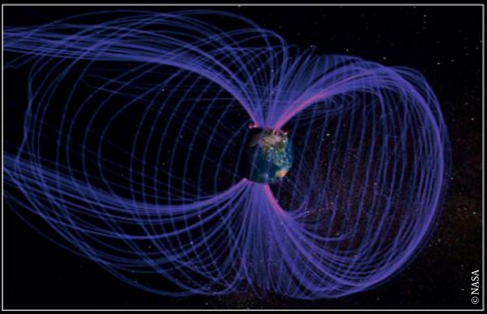

© NASA

Left: Earth is surrounded by a magnetic bubble called its magnetosphere

> "WITH ITS THICK ATMOSPHERE AND YELLOW SUNLIGHT, MUCH OF EARTH'S VEGETATION IS GREEN"

COMPOSITION

32.1%	IRON
30.1%	OXYGEN
15.1%	SILICON
13.9%	MAGNESIUM
2.9%	SULPHUR
1.8%	NICKEL
1.5%	CALCIUM
1.4%	ALUMINIUM
1.2%	TRACES OF OTHER ELEMENTS

NEWS FROM EARTH

Extinction event

A study published in the journal *Biological Conservation* suggests that 84 per cent of animals and plants in mountain regions risk being wiped out if the temperature rises by more than an average of three degrees Celsius (5.4 degrees Fahrenheit), with this rising to 100 per cent on islands.

Geographically unique species such as Madagascar's lemurs and the snow leopards of the Himalayas are 2.7 times more likely to go extinct than species that are more widespread. More than 60 per cent of unique tropical species are likely to go extinct thanks to the action of climate change alone, and places such as the Caribbean islands and Sri Lanka could lose most of their endemic plants by 2050. Up to 92 per cent of species on land and 95 per cent of those in the sea could face negative consequences.

The researchers – from Brazil, Norway and South Africa, among others – concluded that if the world can keep global average temperature rises within the terms of the Paris Climate Agreement, then the risk to vulnerable species drops by a factor of ten. With a 1.5 degrees Celsius (2.7 degrees Fahrenheit) rise, only two per cent of land and marine species face extinction.

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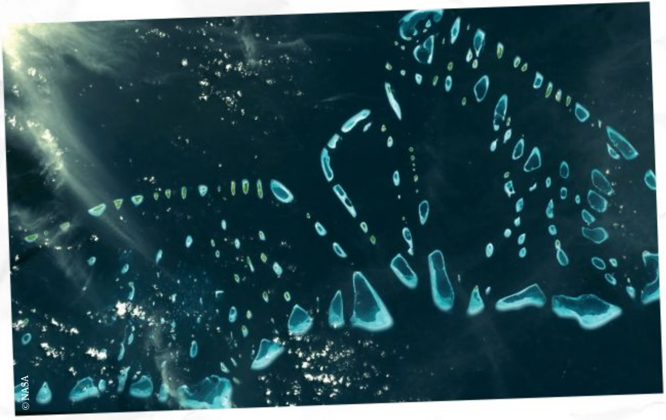
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Artificial island

Not content with all the islands already available to it, the dominant mammal species on Earth has been busy making more. A new artificial island near Malé, the capital of the Republic of Maldives, an archipelago in the Indian Ocean, will act as a refuge for people stranded by rising sea levels. With more than 80 per cent of its 1,190 islands just one metre (3.2 feet) above the water, the Maldives has the lowest terrain of any country in the world, which makes it particularly susceptible to sea-level rise. Construction of the new island, known as Hulhumalé, began in 1997, and it has grown to over four square kilometres (1.5 square miles) in area. It sits two metres (6.5 feet) above sea level, constructed from sand pumped on top of submerged coral, and is now the fourth-largest island in the archipelago.

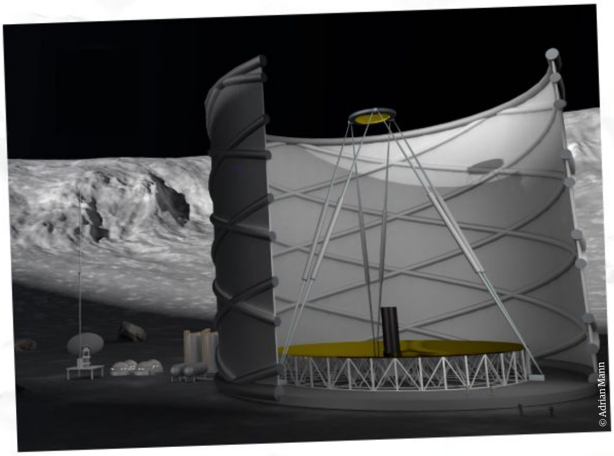
With sea levels predicted to rise by up to half a metre by 2100 even if the Paris Climate Agreement targets are hit, land reclamation projects like this may become more common as populations are driven from low-lying areas.

Moon telescope

An early stage proposal has received funding from NASA to build a radio telescope in a crater on the far side of the Moon. Similar in concept to the Arecibo Observatory, the Lunar Crater Radio Telescope would take advantage of the Moon's many meteor craters to support its structure.

Because of the way Earth and the Moon are tidally locked, one side of the Moon always faces away from us. The advantage of building such a device on the Moon, particularly on its far side, is the shielding effect it gives against Earth-generated noise and even the radio waves emitted by the Sun. It would also be able to observe the universe at frequencies that are blocked by Earth's atmosphere, such as those below 30MHz. Observations in these wavebands have never been made by humans.

The proposal is to deploy two wall-climbing robots in a crater three to five kilometres (1.8 to 3.1 miles) in diameter. The robots would then weave a dish one kilometre (0.62 miles) across using a wire mesh. A receiver would then be suspended above this dish on two crossed cables, each end held by a robot that would be able to move, adjusting the position of the receiver for the best results.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SURFACE WATER AND OCEAN TOPOGRAPHY MISSION

Due to launch in April 2022, SWOT – a joint development between NASA and French space agency CNES, with help from Canada and the UK – is designed to accurately measure the height of Earth's surface water. The SWOT mission aims to measure how bodies of water change over time. It will use a radar altimeter to measure the height of oceans, rivers and lakes across 90 per cent of the globe at least twice every 21 days at an average precision better than 1.5 centimetres (0.6 inches).

This data will lead to better weather and climate forecasting, providing more accurate information about sea and river levels that can be plugged into the supercomputer prediction models used by meteorological agencies. It will also be able to measure the 3D shape of floodwater, track flood levels and improve our ability to predict future floods.

The largest effect SWOT may have on Earth's population is the data it will provide about freshwater management. This will help urban planners to manage the distribution of water for agricultural, industrial and urban needs by providing information about reservoirs and major rivers. The enhanced knowledge we will gain of Earth's water cycle and ocean circulations will help us to better understand everything from surface water to the deep oceans, and this should improve our reactions to natural disasters, waterborne diseases, sharing water sources among different populations and countries, as well as managing electricity production from renewable means and safeguarding biodiversity.

Below: Artist's model of the SWOT spacecraft

© NASA

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PLANET EARTH BY NUMBERS

43KM
The difference in the Earth's diameter at the equator than if measured pole-to-pole

ONE NATURAL SATELLITE

ONE ATMOSPHERE
Mean surface pressure

14°C
Average surface temperature

1G
Average surface gravity

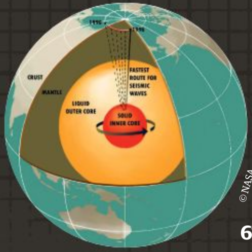
5,430°C
Temperature at inner core

1AU
Average distance to Sun

THE EVOLUTION OF PLANET EARTH

- **Date:** 4.54 billion years ago
  Activity: Earth formed from a protoplanetary disc around a young star.
- **Date:** 4.5 billion years ago
  Activity: Dense elements sank to the centre, forming Earth's core, while the outside layer cooled and solidified.
- **Date:** 4.48 billion years ago
  Activity: A massive impact with another body sent a portion of Earth's crust into orbit, forming the Moon.
- **Date:** 4.4 billion years ago
  Activity: Volcanism released water vapour into Earth's atmosphere, raining down to begin the formation of oceans.
- **Date:** 3.5 billion years ago
  Activity: Earth's magnetic field was established, with a magnetosphere about half the modern radius.
- **Date:** 750 million years ago
  Activity: The earliest known supercontinent, Rodinia, began to break apart.
- **Date:** 180 million years ago
  Activity: The most recent supercontinent, Pangaea, broke apart.
- **Date:** 65 million years ago
  Activity: Formation of the Himalayas began as the Indian subcontinent drifted into Asia.
- **Date:** 6 million years ago
  Activity: A small African ape began a family tree that led to a dominant species.

Below: The structure of the Earth from the surface crust down to the solid inner core



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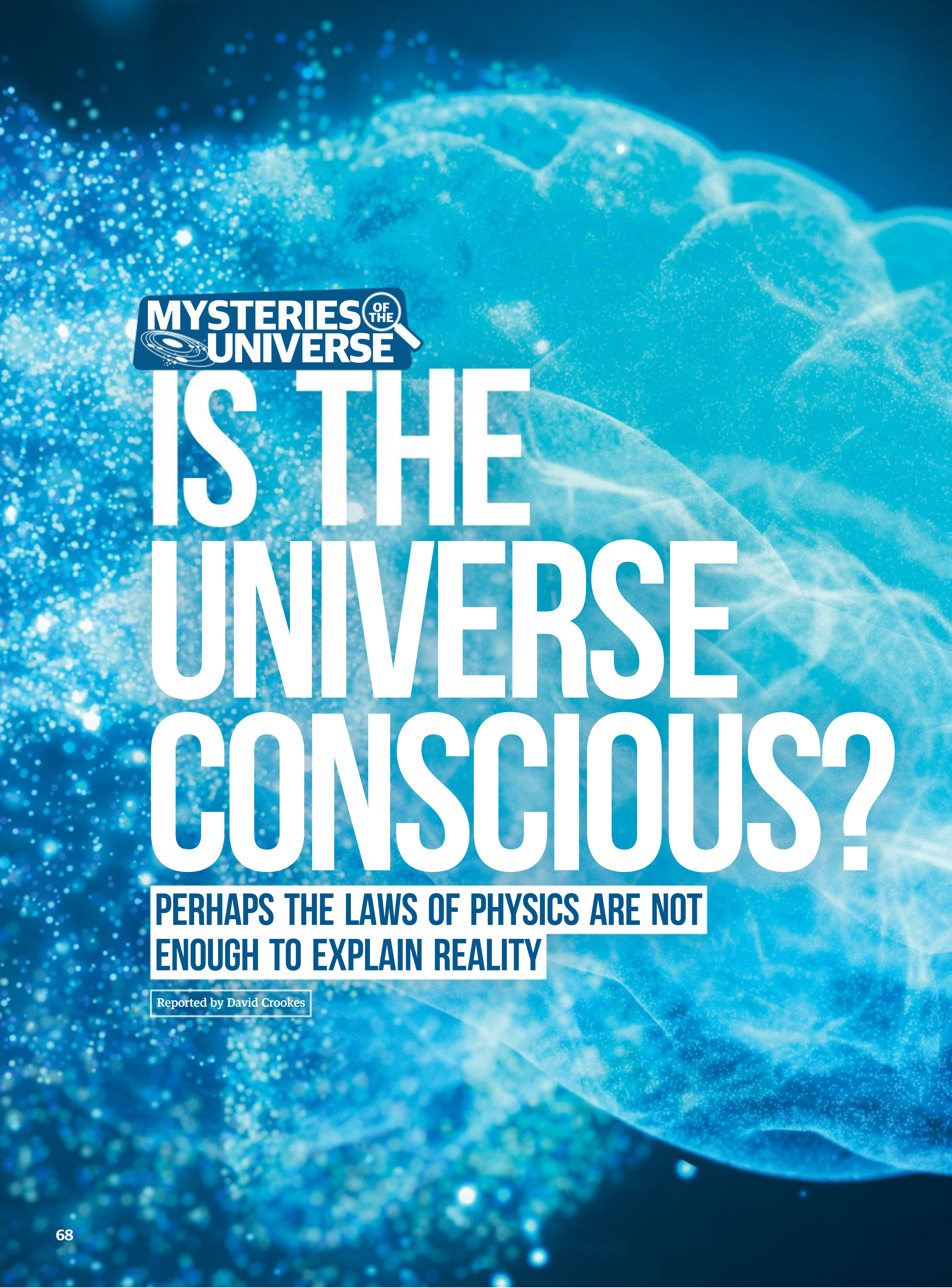

MYSTERIES OF THE UNIVERSE

IS THE UNIVERSE CONSCIOUS?

PERHAPS THE LAWS OF PHYSICS ARE NOT ENOUGH TO EXPLAIN REALITY

Reported by David Crookes

© Getty

Leading scientists have long pondered how matter gives rise to our subjective experience of reality, believing consciousness could even permeate the cosmos

Consciousness has long proven to be a mystery. We know we are conscious because we experience and feel things. Yet scientists and great thinkers are unable to explain exactly what consciousness is. "Consciousness – or conscious experience – is obviously a part of reality," affirms mathematician and theoretical physicist Johannes Kleiner. "We're all having it. It's very likely that many animals have it too. But without understanding how it relates to known physics, our understanding of the universe is incomplete."

It's a bold statement. But there is a pervading thought that consciousness is not confined to humans, or even animals. Though many scientists say you remove a brain and lose consciousness, Buddhists believe consciousness is not dependent on the physical body – that it comprises four layers and continues always like a stream of water.

But even putting religion to one side, there is panpsychism, a philosophical point of view that claims consciousness is inherent in even the tiniest pieces of matter. That sounds like a trippy theory, and yet it's one which appears to be gathering pace.

What's more, panpsychism isn't an idea being peddled by people in tinfoil hats. It is being pursued by top scientific and philosophical minds, among them Dr Philip Goff, associate professor of philosophy at Durham University.

"According to panpsychism the fundamental building blocks of reality have conscious experience," Goff says. "Perhaps the fundamental building blocks are fundamental particles, such as electrons and quarks. But many theoretical physicists think that the fundamental entities are universe-wide fields, and particles are merely local excitations in those fields. If you combine that view with panpsychism, then these fields are the complex experience of the universe itself."

Kleiner is among those looking to pin down whether inanimate matter could be conscious. In doing so, he's studying whether the universe as a whole could be conscious too. For many all of this may seem like a giant leap forward. Neuroscience still needs to figure out how our brains operate and how consciousness works, let alone extend that to the universe as a whole. But for an ultimate scientific account of reality, Kleiner says we need to include consciousness alongside gravity, electromagnetism and the nuclear forces. And how our brains work is fundamental to such work.

"Many models of consciousness have been proposed, and most tie consciousness to the brain in some way," says Kleiner. "But since the brain is actually a very complicated system – some say the most complicated known to humankind – you can only go so far in describing it in plain words.

"Eventually you need maths to describe how neurons are wired together, how they exchange

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A CONSCIOUS UNIVERSE BY NUMBERS

19TH CENTURY

When panpsychism was the default Western philosophy

95%

Amount of dark matter thought to exist in the universe

1

Scientist Gregory Matloff believes panpsychism could help explain dark matter

20TH CENTURY

When logical positivism largely took the place of panpsychism

1989

Year Sir Roger Penrose published *The Emperor's New Mind*

86,000,000

Neurons in a human brain

2004

Year Giulio Tononi proposed his Integrated information theory

0

Level of phi that indicates a lack of consciousness

>0

Level of phi at which consciousness begins to rise

Below: Can a philosophical view align with science? Some scientists are taking panpsychism seriously with the notion that everything in the universe is potentially conscious

Below (main): Is everything in the Milky Way - and in galaxies throughout the universe - conscious? Mathematics is being used to find out

signals and how they process these signals. Mathematical models of consciousness allow us to be more precise in proposing how consciousness attaches to brains."

According to Kleiner, such models can act as a jumping point. "A mathematical theory can be applied to many different systems, not just brains," he says, adding that the models are looking not at the various brain areas scientists have named in the past, but at the interactions between the various components.

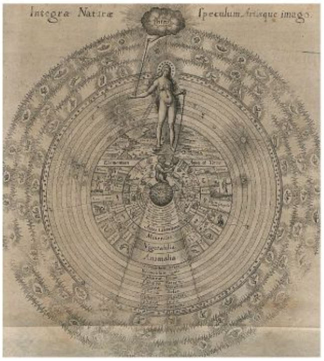
"If you develop a mathematical model of consciousness based on data from brains, you can apply the model to other systems, for example computers or thermostats, to see what it says about the conscious experience of these systems." His task is to take models from neuroscience that have been formulated in words and translate them into mathematical terms. "This will make them more precise and more general," he attests. But his work is only the latest in a long line of pursuits.

There have been some large steps forward in the drive to explore whether the universe is conscious. Renowned Oxford physicist Sir Roger Penrose, for instance, was among the first to propose that we go beyond neuroscience when looking at consciousness, saying we should strongly consider the role of quantum mechanics.

In 1989 he published *The Emperor's New Mind*, arguing that human consciousness is non-algorithmic and a product of quantum effects. Along with anaesthesiologist and psychologist Stuart Hameroff, Penrose developed a hypothesis, called orchestrated objective reduction (Orch OR), which claims consciousness is likely due to quantum vibrations in microtubules deep within brain neurons. So what does this have to do with the universe being conscious? A paper they wrote in 2014 states that "Orch OR suggests there is a connection between the brain's biomolecular processes and the basic structure of the universe".

Crucially, they also wrote: "We conclude that consciousness plays an intrinsic role in the universe." For them consciousness results from discrete physical events. "Such events have always existed in the universe as non-cognitive, proto-conscious events, these acting as part of precise physical laws not yet fully understood," the paper said of this possibility.

It's difficult to prove. In 1995, philosopher David Chalmers coined the phrase 'the hard problem of consciousness', fully realising the tricky nature of answering how and why neurophysiological



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IS PARANEGO'S DISCONTINUITY PROOF OF A CONSCIOUS UNIVERSE?

Physicist Gregory Matloff suggests the behaviour of some stars could show they are responding consciously to stimuli

DIFFERING SPEEDS

Paranego's discontinuity is an anomaly in stellar motion that has proven intriguing: red, cooler stars orbit our galaxy at a faster pace than blue, hotter ones.

ESTABLISHED EXPLANATION

Scientists suppose the anomaly, based on data from the ESA's Hipparcos mission which ran between 1989 and 1993 and supplemented from a dataset from Gaia, happens because of the way the stars interact with gas clouds.

MOLECULES IN THE ATMOSPHERE

Matloff said cool stars could have chemistry – they could be so sufficiently cool as to have molecules in their atmospheres. Velocity, he said, was related to star type.

A PSYCHOKINETIC EFFECT?

Although Matloff doesn't advocate psychokinesis, he said some stars emit jets of extremely high energies in one direction and that they deliberately altered their motion in the direction that they were rotating in.

A LEVEL OF CONSCIOUSNESS

The question is could the stars have a level of consciousness – are they deliberately controlling their own movement? The idea was raised in Matloff's paper, *Can Panpsychism Become an Observational Science?*

© Getty

activities produce the experience of consciousness. Kleiner is also having a good stab at it. His work is being inspired by neuroscientist and psychiatrist Dr Giulio Tononi, distinguished chair in consciousness studies at the University of Wisconsin. Tononi's integrated information theory (IIT) is one of a small class of very promising models of consciousness. "IIT is very different because it's a very mathematical theory, and this very fact – that it is formulated in precise mathematical terms – is very important and endows the theory with a guiding role for the development of the field," Kleiner says.

Working with Sean Tull, a mathematician at the University of Oxford, Kleiner is basing his work on IIT's core idea that consciousness can be explained in physical terms. Tononi collaborated with Gerald Edelman at the Neurosciences Institute in San Diego, and the pair wrote *A Universe of Consciousness* in 2000, which suggested consciousness will emerge when information moves between subsystems of an overall system.

It says consciousness is a fundamental aspect of reality: that it exists and that it is structured, specific, unified and definite. What is important, however, is how complex the system is. To be conscious an entity has to be single and integrated, and it needs to possess a property called 'phi', which is dependent on the interdependence of the subsystems. In other words, you could have a bunch of coins on your desk, and on top of each sits a bunch of neurons. If information which travels along those pathways is crucial for those coins, then you've got a high phi, and therefore consciousness.

If those coins could operate perfectly well as subsystems without information flowing to and from other coins, then there is no phi, and there is no consciousness. The greater the interdependency between subsystems, the more conscious something will be, and so it's about whether a system is more than the sum of its parts, as Christof Koch, the Lois and Victor Troendle professor of cognitive behavioural biology at the California Institute of Technology, wrote in *Scientific American* in 2009.

"Integrated information is an abstract quantity which you can calculate if you have a good, detailed description of the system," Kleiner says. The result is a number, denoted by phi, so if you have an apple you can ask how much integrated information is in there, just as you can ask how much energy is in there. You can talk about how much integrated information is in a computer, just like you can talk about entropy."

The system doesn't have to be biological. It doesn't have to relate to humans or other living creatures. "IIT says that a system is conscious if – and only if – it has integrated information," Kleiner says. "If you're an apple, which has no integrated information, phi is zero and you're not conscious. If you're a thermostat, which has some integrated information, albeit only a little bit, you are a little bit conscious."

In many respects IIT backs panpsychism, because even a proton can possess phi, according to the theory. And just as an apple, thermostat and computer can possess it, so can all manner of other things across the universe. "When it comes to experimental evidence, there are several independent studies which point at a correlation between integrated information and consciousness," Kleiner affirms.

So do subsystems have conscious experience? No. Is any system conscious? No. We've already seen that an absence of phi in a system means there is no consciousness. "The theory consists of a very complicated algorithm that, when applied to a detailed mathematical description of a physical system, provides information about whether the system is conscious or not, and what it is conscious of," continues Kleiner.

"The mathematics are such that if something is conscious according to the theory, then the components which make up that system can't have conscious experiences on their own. Only the whole has conscious experience, not the parts. Applied to your brain, it means that some of your cortex might be conscious, but the particles that make up the cortex are not themselves conscious."

What does that mean for the universe? "If there's an isolated pair of particles floating around somewhere in space, they will have some rudimentary form of consciousness if they interact in the correct way," Kleiner explains. According to IIT, the universe is indeed full of consciousness. It's all over the place, and many things which we didn't think were conscious do have some conscious experience. But does it have any implications for the physical part of the universe? According to the maths of the theory, no. A physical system will operate independent of whether it has a conscious experience or not. Kleiner gives a computer as an example, saying that IIT's maths shows it may have consciousness, but that won't change the way in which it operates.

"This is at odds with the metaphysical underpinning of the theory, which is strongly idealist in nature," he says. "It puts consciousness first and the physical second. We might see some change in the mathematics at some point to take this underpinning more properly into account."

This is what his and Tull's study seeks to resolve. Emergentist theories of consciousness tend to claim physics is all there is. "They would reject the idea that consciousness is separate from or more primary than the physical, and they would say consciousness is nothing but a specific physical phenomenon which emerges from the interaction of the fundamental physical quantities in certain conditions," Kleiner says.

His and Tull's mathematical version of IIT, on the other hand, is intended to be what could be called a fundamental theory of consciousness. "It tries to weave consciousness into the fundamental fabric of reality, albeit in a very specific way," Kleiner tells us. If it's shown that the universe is conscious, what then? What are the consequences?

"There might be moral implications. We tend to treat systems which have conscious experiences different from systems which don't," Kleiner answers. "Most of us don't, for example, attach emotion to our laptops: if they break down, we don't worry about the laptop for its own sake. But if our pet is hurt, we worry about the pet for its own sake. There are implications here for artificial intelligence (AI). If there was proof AI systems were conscious, we might have to adapt some of our behaviour and possibly also some of our laws."

Even so, scepticism still remains. Goff says we shouldn't be surprised that our current scientific approach struggles to capture the qualities of experience because our current scientific approach was designed to exclude them. He tells us that science has worked with a purely quantitative description of the physical world ever since the

PUTTING CONSCIOUSNESS BACK INTO THE COSMOS

Dr Philip Goff, a philosopher and consciousness researcher at Durham University, thinks everything in the physical world has a degree of consciousness. He's the author of *Galileo's Error: Foundations for a New Science of Consciousness*

Panpsychism says that all things have a mind-like quality, thereby pointing to the possibility of the universe being conscious, but how does it explain this?
The current resurgence of interest in panpsychism is rooted in important work from the 1920s by the philosopher and Nobel laureate Bertrand Russell and the scientist Arthur Eddington, who was, incidentally, the first scientist to experimentally confirm Einstein's general theory of relativity.

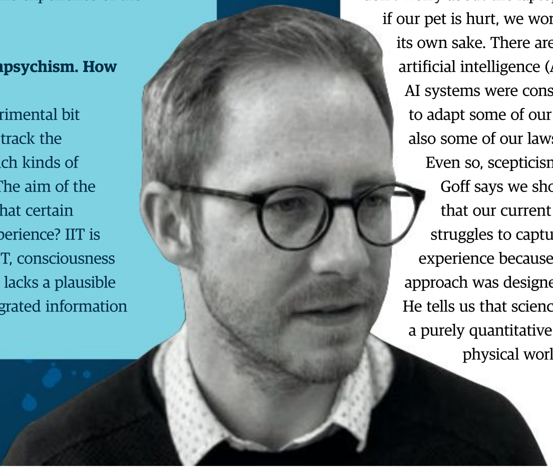
The starting point for Russell and Eddington is that physical science tells us what matter does, but it doesn't tell us what it actually is. Physics tells us, for example, that particles have mass and charge, and these properties are completely defined in terms of behaviour: things like attraction, repulsion and resistance to acceleration. This is all about what stuff does. Doing physics is like playing chess without knowing what the pieces are made of.

The genius of Russell and Eddington was to see the connection to the problem of consciousness. If physics leaves completely open what an electron is, then physics is left open to the theoretical possibility that an electron is a form of consciousness. Russell and Eddington saw the potential for bringing together what Galileo Galilei had separated: the quantitative story of physics and the qualitative story of consciousness. According to panpsychism, the former is the story of what matter does, while the latter is the story of what matter is. Matter and consciousness are inseparable: two sides of the same coin.

When people say 'the universe might be conscious', what do they mean?
It is important not to anthropocentrically focus on human consciousness: nobody is claiming that an electron has the consciousness of a human being. What it's like to be a human being is a rich and complex affair involving detailed visual and auditory experiences, deep emotions, and subtle thoughts. What it's like to be a sheep is significantly simpler. What it's like to be a mouse is simpler still. As we move to simpler and simpler forms of life, we find simpler and simpler forms of conscious experience. It's possible that this continues right down to the basic building blocks of matter, with electrons and quarks having incredibly simple forms of conscious experience to reflect their incredibly simple nature.

If the universe has experience, on the other hand, it will be incredibly complex, corresponding to the complex physical structure of space and time. However, that doesn't mean the universe is a kind of self-aware, intelligent agent. You need millions of years of evolution to get these traits. Rather, the experience of the universe is probably just a meaningless mess.

Integrated information theory is compatible with panpsychism. How can it explain consciousness?
We can divide the science of consciousness into an experimental bit and a scientific bit. The aim of the experimental bit is to track the neural correlates of consciousness (NCC) to work out which kinds of brain activity correspond to which kinds of experience. The aim of the theoretical bit is to explain these correlations. Why is it that certain kinds of physical activity give rise to certain forms of experience? IIT is one answer to the experimental question: according to IIT, consciousness is correlated with maximal integrated information. But it lacks a plausible answer to this theoretical question: why is maximal integrated information correlated with experience?



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father of modern science, Galileo Galilei, declared mathematics the language of the new science.

"Galileo understood quite well that we can't capture the qualities of experience in the quantitative language of mathematics, and so he banished consciousness from science, locating it in the soul rather than in matter," Goff says. "Only once conscious experience was out of the way was mathematical physics possible."

As such, he sees no problem using mathematics to capture the structure of experience. "Colour experiences, for example, can be analysed in the three dimensions of hue, saturation and brightness, and we can map out a space of similarity and difference between colours along these three dimensions," he tells **All About Space**.

"But purely quantitative descriptions of colour experience will never fully capture what it's like to have a colour experience; they will never convey to a colour-blind scientist the character of a red experience. So long as our description of the brain is framed in the purely quantitative vocabulary of mathematics, we'll leave out the qualities of experience, and hence leave out the essence of consciousness itself."

For Goff the problem of consciousness could be solved if we integrate the quantitative story of physical science with the qualitative story of human consciousness into a unified theory of reality, something he says panpsychism is able to do. "We need to bring qualities – colours, sounds, smells and tastes – back into the scientific story. This is what panpsychism is able to do."

To that end, the concept of a conscious universe is very much one to be explored. After all, if it's proven that consciousness plays a causal role in the universe, it would have huge consequences for the scientific view of the world. "It could lead to a scientific revolution on par with the one initiated by Galileo," Kleiner says.

David Crookes

Science and technology journalist

David has been reporting on space, science and technology for many years, has contributed to many books and is a producer for BBC Radio 5 Live.

Above: Could proving the universe is conscious make us rethink our theories about dark matter?

Below: Could objects we use be as conscious as our own brains, and how far reaching could consciousness be?

© Getty

THE THEORIES

Just what could consciousness be?

1 MATERIAL INTERACTION

Most scientists are materialists: they explain consciousness as causally dependent on physical processes and hold that only matter has been proven to exist. In other words, consciousness is a result of a material interaction between, as an example, the body's nervous system and the brain's biochemistry. It's implicitly atheist.

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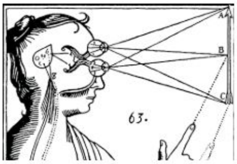
SOMETHING APART FROM THE BODY

Dualism explains consciousness as being separate from the body and brain. As such, this philosophical view holds that mental phenomena are non-physical, and proponents argue that the mind is not the same as the brain. René Descartes, the 17th-century French philosopher, reached such a conclusion. Other mind-body dualism theories have since emerged.



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THE NATURE OF MATTER ITSELF

Derived from the Pre-Socratic Greek philosopher Thales of Miletus, panpsychism is a view that fundamental particles, as well as humans, are conscious. It agrees that the world is wholly physical, but that consciousness can be explained by what matter is rather than what it does. But there's a combination problem: how do the experiences of subatomic particles combine?

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ASK **Space**

Our experts answer your questions

SOLAR SYSTEM

What would we do if a massive asteroid was on a collision course with Earth?

What we would do depends on how much time we have before impact. The NASA-funded Catalina Sky Survey in Tucson, Arizona, where I work, discovers a number of new near-Earth asteroids every clear night. Some of these are very small and can only be spotted when they are close to Earth. These pose no threat to Earth even if they hit.

Our task is to find the massive asteroids many years, decades or, better still, centuries before they may impact. The further into the future the impact will occur, the easier the task of avoiding the collision in the first place. With a long lead time there are many options available to us. In this case we only need a slight change in the velocity to avoid the collision far in the future.

The less lead time before impact, the fewer viable options we would have. A much greater effort would be required to accomplish the goal as well. With a long lead time, a gravity tractor or even 'painting' the surface of the asteroid with a white powder so just the pressure of sunlight moves the asteroid are viable options.

Richard A. Kowalski, senior research specialist, Lunar and Planetary Laboratory, University of Arizona

Below: Artist's impression of an asteroid impact

© Tobias Roetsch

Right: NASA's Hubble Space Telescope's wide view of the universe

© NASA, ESA and the Hubble Legacy Field team

Did you know?

As of 2021, over 25,000 near-Earth asteroids – also known as near-Earth objects – are thought to exist.

COSMOLOGY

Why is space a vacuum?

While things are quite crowded here on Earth, outer space is not. Scientists refer to space as a vacuum, a region of extremely low density, where density is a measure of the amount of 'stuff' in a given volume. The density of the air you breathe is about one kilogram per cubic metre [35 cubic feet], whereas the density of a cast-iron frying pan is 10,000 times larger. But the densities found in interstellar space are far lower, about a trillion trillion times less than that of air.

The reason for the extremely low densities is simple: there is not very much matter in the universe relative to its vast volume. Dense corners of the universe like Earth are exceedingly rare - most of the universe is just empty. But it was not always so. In the few minutes just after the Big Bang, the density of the universe was so high it rivalled that of the cores of stars. As the universe expanded, its density dropped dramatically. Gravity only amplified this effect, pulling matter together into dense pockets like stars and planets, but at the cost of separating them by exceedingly empty voids: the vacuum of space.

Cameron Hummels, computational astrophysicist at Caltech

HUNT FOR LIFE

What are biosignatures?

Biosignatures are imprints that life leaves behind on our universe. Biosignatures can be used as scientific evidence for past or present life. When searching for extraterrestrial life, we use the one example of life we have on Earth as our guide. A biosignature can be the fossil bones of ancient animals, the imprint of plant leaves on a rock or biomolecules like our DNA.

Most biosignatures, however, are based on Earth life. Because of this, we often impose a bias on our search for extraterrestrial life by expecting them to share a similar chemical make-up as Earth life. The future of biosignature research is to broaden our search horizon by relaxing our assumptions about what life could look like elsewhere.

Agnostic biosignatures are those that do not presuppose the presence of a particular biochemistry. They allow us to focus more on traits of life that could be universal, such as the presence of highly complex molecules that require life, or lifelike machineries, to produce, or the flow of electrons that is inconsistent with non-biological processes. Future missions like ExoMars' Rosalind Franklin rover and the Dragonfly mission to Titan contain instruments that allow us to look for these agnostic biosignatures.

Luoth Chou, postdoctoral fellow at NASA's Goddard Space Flight Center and Georgetown University

Below: Artist's impression of a DNA molecule floating in water

© Getty

ASK Space

Our experts answer your questions

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SPACE EXPLORATION

Do low-Earth orbit satellites impact ground-based astronomy?

Yes, and it's increasing. While humans have been launching satellites for over 60 years, we are witnessing a new era as the skies fill with thousands of satellites. Satellites reflect sunlight, and global satellite coverage will cause bright streaks in images for large portions of the night. Unlike in radio, where frequency bands are regulated, there is no limit on the number or brightness of satellites launched.

Not only is science impacted, but so are astronomers' careers and the shared human experience of a dark sky. Satellite operators can somewhat mitigate the impacts. Orbits can stay below 600 kilometres (373 miles), satellites can be darkened and operators can share trajectories. Software can be developed to remove satellite streaks, but this is not a panacea. As the 2020 Satellite Constellations 1 workshop report concluded: "No combination of mitigations can fully avoid the impacts of the satellite trails on the programs of current and planned ground-based facilities."

Dr Meredith Rawls, research scientist at the University of Washington

Left: Satellites with a high reflectivity can be especially disruptive

© Caltech

Above: Planet Nine is a hypothetical giant planet beyond Neptune

SOLAR SYSTEM

Why do we believe Planet Nine exists?

The trans-Neptunian Solar System is a lonely place. The Sun appears dim, and fragments of icy debris – colloquially referred to as Kuiper Belt objects (KBOs) – drift through space, slowly tracing out their elliptical paths. This frigid province of our cosmic home is also strikingly mysterious.

Close to the Solar System's plane, the orbits of long-period KBOs cluster together as if they had been haphazardly arranged by a cosmic florist into a bunched bundle of trajectories. Some of these orbits are considerably less elliptic than they should be, and even at perihelion remain dynamically detached from Neptune. Others have orbital tilts so extreme they orbit the Sun 'upside-down'. What's going on? A riveting possibility is that all these anomalies are interconnected and collectively point to the gravitational pull of a single distant entity: Planet Nine.

Over the last five years, we have carried out detailed simulations of the Solar System's long-term evolution and have demonstrated that if Planet Nine is a five-Earth-mass body that orbits the Sun on a mildly eccentric and slightly tilted orbit with a period of about 10,000 years, then each of these pieces of the puzzle naturally fall into place.

Dr Konstantin Batygin, professor of planetary science, Caltech

ASTROPHYSICS

Why do comets have two tails?

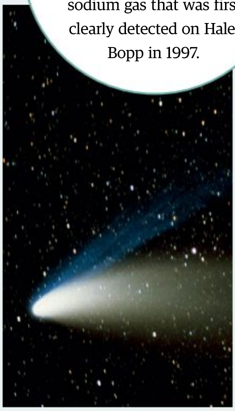
Comets have two visible tails because different physics acts on the dust and gas they release. We see dust grains released by comets because they reflect sunlight. When light is reflected it exerts a very weak force called 'radiation pressure' that pushes the microscopic dust away from the Sun. Over days and weeks the dust forms a curved tail as it moves away from the comet. Dust tails are often the brightest tails we see, for example in Comet NEOWISE last year, because dust reflects light at all wavelengths.

Some of the gas molecules released by a comet lose an electron and become electrically charged. This ionised gas is picked up by the magnetic field in the solar wind streaming away from the Sun. As the solar wind is travelling faster than the comet in its orbit, this creates an ion tail pointing almost directly away from the Sun. Ion tails are often fainter, and generally appear blue in photos because ionised carbon monoxide emits light at blue wavelengths.

Professor Alan Fitzsimmons, School of Mathematics and Physics, Queen's University Belfast

Did you know?

Comets have a tail of uncharged sodium gas that was first clearly detected on Hale-Bopp in 1997.


© Getty

Right: Comet Hale-Bopp

STARS

What makes binary stars so important to astronomers?

Binary stars are important because unlike our shiny host star, the Sun, most stars in the universe - Sun-like or more massive - are in pairs. As stars are the building blocks of galaxies and stellar clusters, by studying binary systems we can understand many astronomical processes in the cosmos. By spotting how binary stars move around one another, we can infer their masses. From that we can also work out their radii, luminosities and densities. These quantities are important for testing and developing stellar evolution theories.

Amazing processes occur throughout the lives of binary stars, triggered by their interaction. And many times we can witness them across different wavelengths. As a star in a system grows old, a mass exchange can take place which rejuvenates the younger star. We've glimpsed some of these phenomena in radio waves. The corpse of a star can also suck material from a younger star, spewing a fountain of X-rays.

By studying binary stars, we learn how stars live their lives. Even during their afterlives, interesting physics takes place that can help prove theories such as general relativity - and it's that gravitational waves come out of the merging corpses of binary stars.

Dr Martha Irene Saladino is an astrophysicist and science communicator

Below: Artist's impression of exotic binary star system AR Scorpii

© ESA

“AMAZING PROCESSES OCCUR THROUGHOUT THE LIVES OF BINARY STARS, TRIGGERED BY THEIR INTERACTION”

MARTHA IRENE SALADINO

WHAT'S IN THE SKY?

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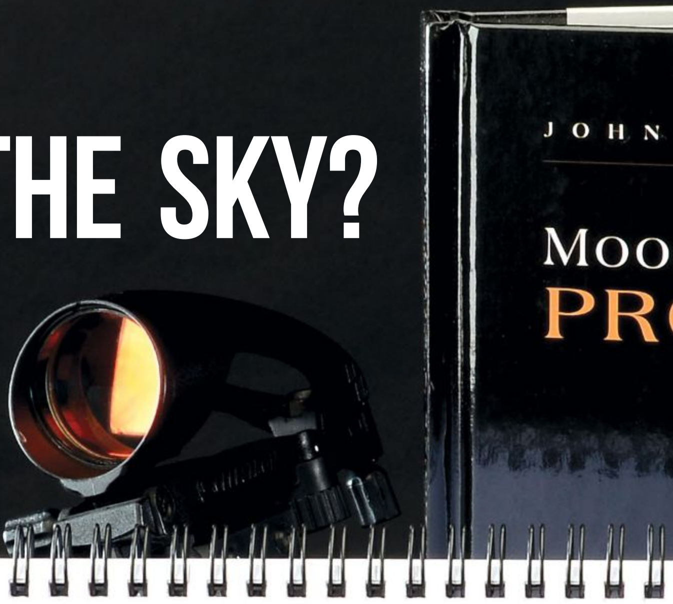

RED LIGHT FRIENDLY

In order to preserve your night vision, you should read our observing guide under red light

26 MAY
Total lunar eclipse visible from Oceania, the Americas and East and Southeast Asia

31 MAY
Conjunction between the Moon and Saturn in Capricornus

31 MAY
The Moon and Saturn make a close approach, within 4°03' of each other in Capricornus

3 JUN
Globular cluster Messier 12 is well placed for observation in Ophiuchus, glowing at magnitude +6.7

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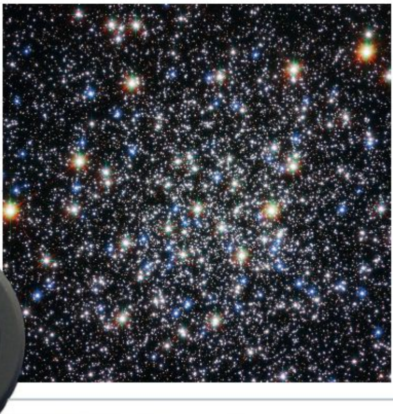
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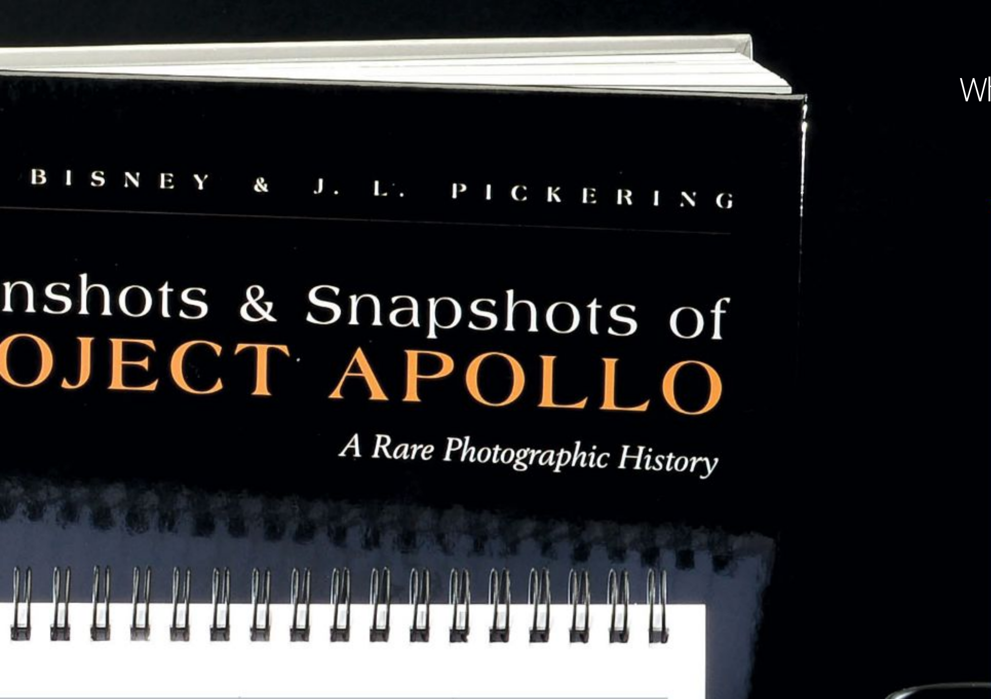
11 JUN
Globular cluster Messier 92 is well placed for observation in Hercules at +6.4



1 JUN

Conjunction between the Moon and Jupiter in Aquarius

1 JUN

The Moon and Jupiter make a close approach, passing within 4°21' of each other in Aquarius

2 JUN

Globular cluster Messier 13 is well placed for observation in Hercules at +5.8

5 JUN

Globular cluster Messier 10 is well placed for observation in Ophiuchus at +6.6

10 JUN

TAKE CARE!

Annular solar eclipse visible from Canada, Russia and Greenland

Source: Wikipedia Commons © Sid Leach/Adam Block/Mount Lemmon SkyCenter

13 JUN

Conjunction between the Moon and Mars in Cancer

13 JUN

The Moon and Mars make a close approach, passing within 2°46' of each other in Cancer

- Naked eye
- Binoculars
- Small telescope
- Medium telescope
- Large telescope

JARGON BUSTER

Conjunction

This is an alignment of objects at the same celestial longitude. The conjunction of the Moon and the planets is determined with reference to the Sun. A planet is in conjunction with the Sun when it and Earth are aligned on opposite sides of the Sun.

Right Ascension (RA)

Right Ascension is to the sky what longitude is to the surface of the Earth, corresponding to east and west directions. It is measured in hours, minutes and seconds since, as the Earth rotates on its axis, we see different parts of the sky throughout the night.

Greatest elongation

This is when the inner planets, Mercury and Venus, are at their maximum distance from the Sun. During greatest elongation, the inner planets can be observed as bright evening stars during greatest eastern elongations and as morning stars during western elongations.

Declination (Dec)

Declination tells you how high an object will rise in the sky. Like Earth's latitude, Dec measures north and south. It's measured in degrees, arcminutes and arcseconds. There are 60 arcseconds in an arcminute and there are 60 arcminutes in a degree.

Magnitude

An object's magnitude tells you how bright it is from Earth. In astronomy, magnitudes are represented on a numbered scale. The lower the number, the brighter the object will be. So, an object with a magnitude of -1 is brighter than an object with a magnitude of +2.

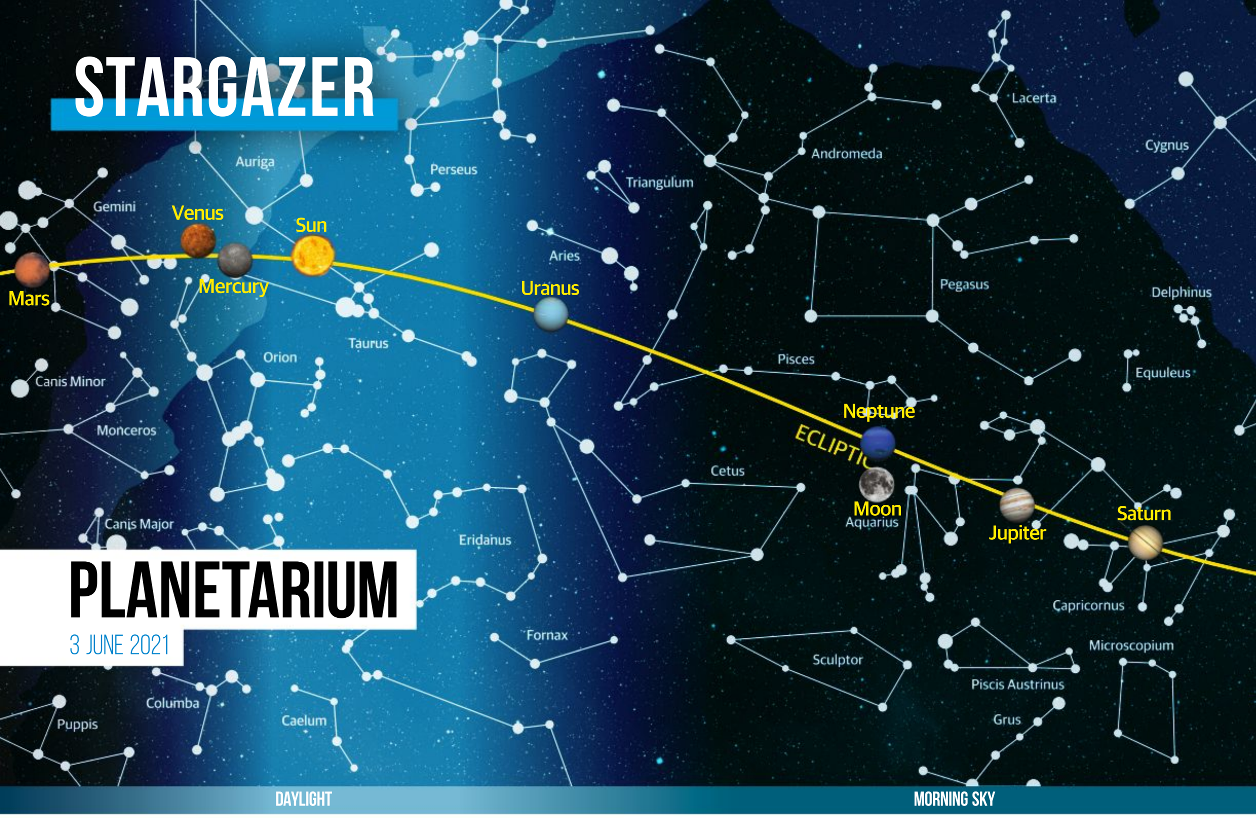
Opposition

This is when a celestial body is in line with the Earth and the Sun. During opposition, an object is visible for the whole night, rising at sunset and setting at sunrise. At this point in its orbit, the celestial object is closest to Earth, making it appear bigger and brighter in the sky.

STARGAZER

PLANETARIUM

3 JUNE 2021



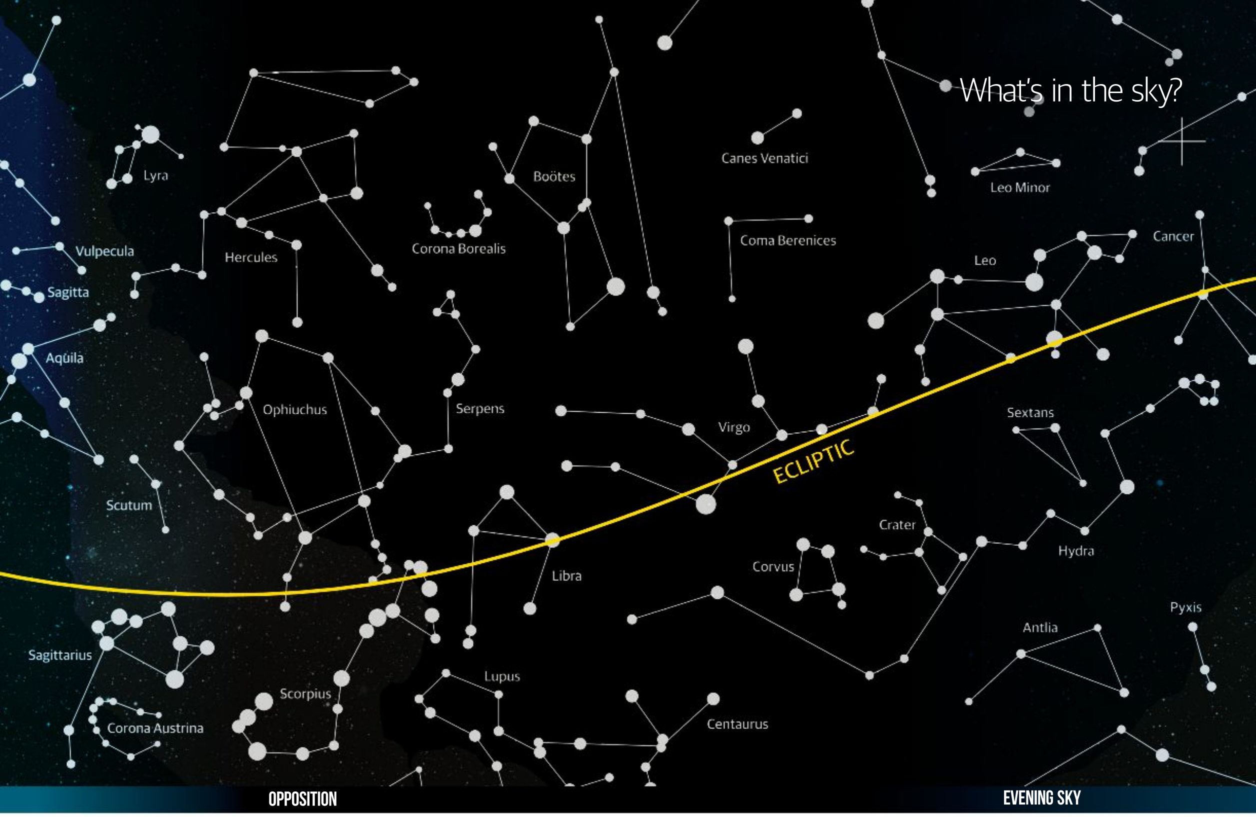
MOON CALENDAR

* The Moon does not pass the meridian on 25 May

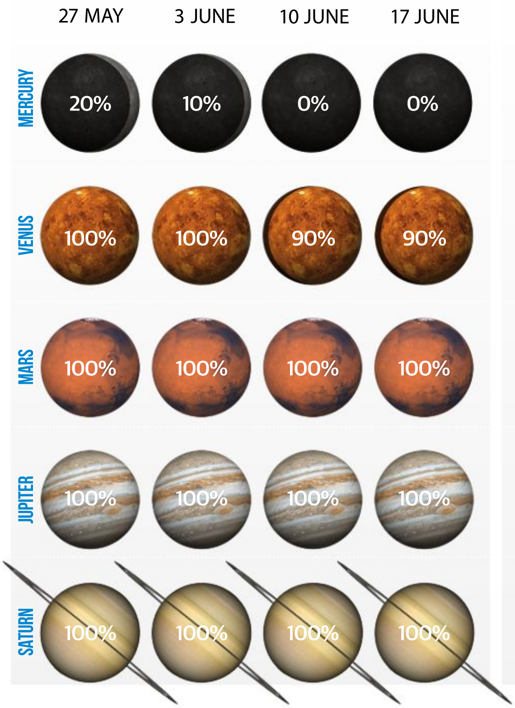
			20 MAY 60.8% ▼02:55 ▲12:45	**21 MAY** 71.7% ▼03:14 ▲14:06	**22 MAY** 81.8% ▼03:31 ▲15:28	**23 MAY** 90.3% ▼03:48 ▲16:54
24 MAY 96.4% ▼04:06 ▲18:22	**25 MAY** --:--%* ▼04:27 ▲19:54	**26 MAY** FM 99.6% ▼04:53 ▲21:25	**27 MAY** 99.5% ▼05:28 ▲22:49	**28 MAY** 96.2% ▼06:16 ▲23:59	**29 MAY** 90.0% ▼07:19 ▲--:--	**30 MAY** 81.6% ▲00:52 ▼08:34
31 MAY 71.8% ▲01:29 ▼09:53	**1 JUN** 61.3% ▲01.56 ▼11:12	**2 JUN** TQ 50.6% ▲02:16 ▼12:27	**3 JUN** 40.3% ▲02:32 ▼13:40	**4 JUN** 30.6% ▲02:47 ▼14:50	**5 JUN** 21.9% ▲03:00 ▼15:58	**6 JUN** 14.3% ▲03:14 ▼17:07
7 JUN 8.2% ▲03:29 ▼18:15	**8 JUN** 3.7% ▲03:46 ▼19:25	**9 JUN** 0.9% ▲04:08 ▼20:33	**10 JUN** NM 0.0% ▲04:35 ▼21:39	**11 JUN** 1.1% ▲05:11 ▼22:37	**12 JUN** 4.2% ▲05:58 ▼23:27	**13 JUN** 9.3% ▲06:55 ▼--:--
14 JUN 16.2% ▼00:06 ▲08:02	**15 JUN** 24.8% ▼00:36 ▲09:15	**16 JUN** 34.7% ▼01:00 ▲10:32	**17 JUN** 45.5% ▼01:20 ▲11:50			

% Illumination
▲ Moonrise time
▼ Moonset time

FM Full Moon
NM New Moon
FQ First quarter
TQ Third quarter



ILLUMINATION PERCENTAGE



	27 MAY	3 JUNE	10 JUNE	17 JUNE
MERCURY	20%	10%	0%	0%
VENUS	100%	100%	90%	90%
MARS	100%	100%	100%	100%
JUPITER	100%	100%	100%	100%
SATURN	100%	100%	100%	100%

PLANET POSITIONS

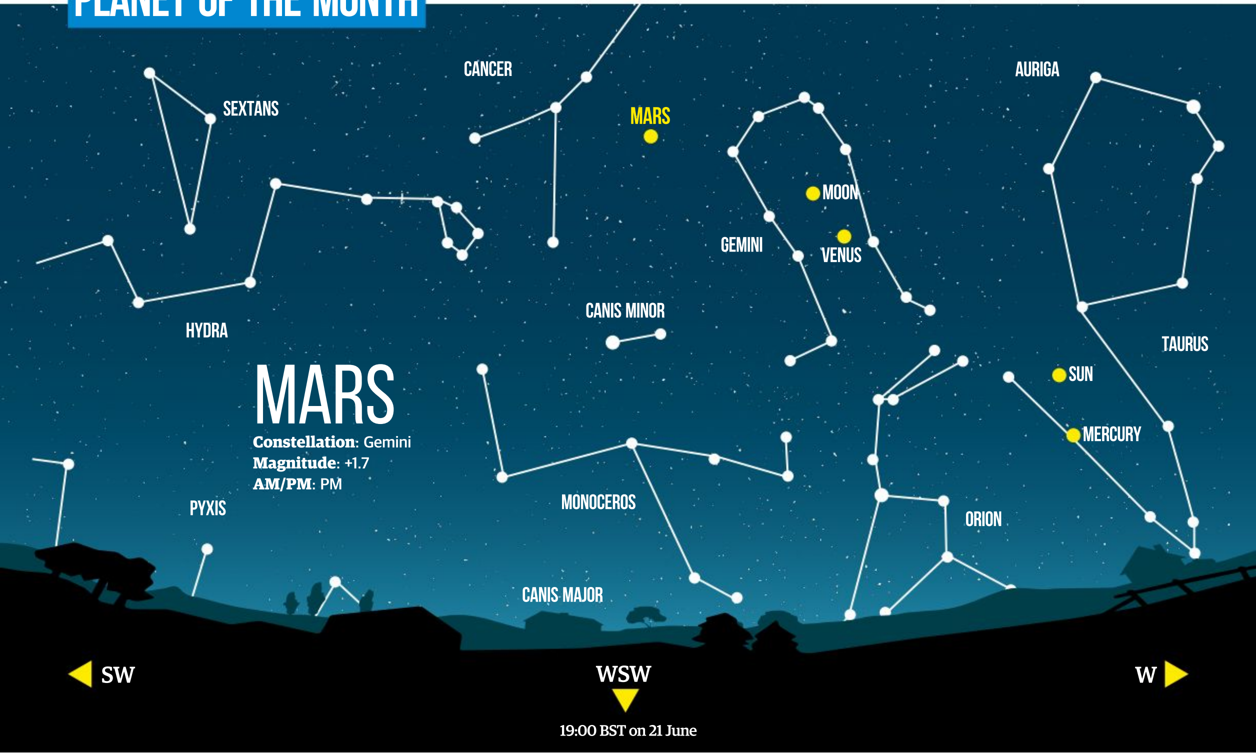
All rise and set times are given in BST

	RA	DEC		MAG	RISE	
20 MAY	05h 18m 17s	+25° 09' 56"	Taurus	+0.7	05:59	23:11
27 MAY	05h 34m 03s	+24° 11' 54"	Taurus	+1.8	05:54	22:51
3 JUN	05h 33m 16s	+22° 22' 17"	Taurus	+3.6	05:39	22:08
10 JUN	05h 20m 09s	+20° 14' 02"	Taurus	+6.1	05:12	21:11
17 JUN	05h 05m 30s	+18° 37' 41"	Taurus	+4.1	04:41	20:18
20 MAY	04h 46m 32s	+22° 47' 28"	Taurus	-3.9	05:44	22:25
27 MAY	05h 23m 37s	+23° 52' 36"	Taurus	-3.9	05:44	22:35
3 JUN	06h 01m 05s	+24° 23' 49"	Gemini	-3.9	05:50	22:50
10 JUN	06h 38m 37s	+24° 20' 00"	Gemini	-3.9	06:02	23:01
17 JUN	07h 15m 53s	+23° 41' 14"	Gemini	-3.9	06:18	23:06
20 MAY	07h 09m 30s	+23° 53' 03"	Gemini	+1.7	08:00	00:51
27 MAY	07h 28m 02s	+23° 17' 17"	Gemini	+1.7	07:53	00:36
3 JUN	07h 46m 25s	+22° 33' 43"	Gemini	+1.7	07:51	00:23
10 JUN	08h 04m 38s	+21° 42' 37"	Cancer	+1.8	07:46	00:05
17 JUN	08h 22m 40s	+20° 44' 21"	Cancer	+1.8	07:45	23:51
20 MAY	22h 10m 48s	-12° 07' 19"	Aquarius	-2.4	02:29	12:27
27 MAY	22h 13m 09s	-11° 56' 12"	Aquarius	-2.4	02:01	12:01
3 JUN	22h 14m 57s	-11° 48' 05"	Aquarius	-2.5	01:36	11:37
10 JUN	22h 16m 12s	-11° 43' 08"	Aquarius	-2.5	01:10	11:12
17 JUN	22h 16m 51s	-11° 41' 30"	Aquarius	-2.6	00:43	10:46
20 MAY	21h 03m 27s	-17° 26' 54"	Capricornus	+0.6	01:54	10:49
27 MAY	21h 03m 28s	-17° 27' 53"	Capricornus	+0.6	01:26	10:21
3 JUN	21h 03m 10s	-17° 30' 13"	Capricornus	+0.6	00:58	09:52
10 JUN	21h 02m 33s	-17° 33' 51"	Capricornus	+0.5	00:29	09:23
17 JUN	21h 01m 38s	-17° 38' 44"	Capricornus	+0.5	00:04	08:56

THIS MONTH'S PLANETS

Catch Mars in the evening sky alongside Mercury and Venus, which put on a dazzling display

PLANET OF THE MONTH



MARS

Constellation: Gemini
Magnitude: +1.7
AM/PM: PM

19:00 BST on 21 June

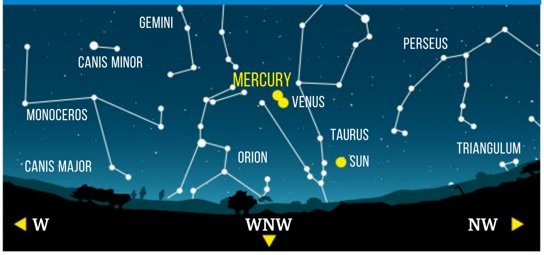
Mars will be visible in the evening sky this month as an orange-hued star, shining halfway up from the western horizon as the sky begins to darken. With a magnitude of +1.7 it will be bright enough to be seen with just the naked eye, but not particularly striking, nowhere near bright enough to catch the eye if you're not looking for it and a lot fainter than much brighter Venus, which will be visible over to its lower right in the northwest.

At the start of our observing period Mars will lie below the 'twin stars' Castor and Pollux in Gemini, and will be setting around three hours after the Sun. By the middle of June, when Mars will have moved closer to the Sun and will be setting an hour earlier, it will have company in the sky. On the evening of 12 June a beautiful crescent Moon will shine to Mars' lower right, halfway between it and Venus. The following evening the Moon will have moved further eastwards along its track and will be just two degrees away from Mars. After sunset on 14 June the Moon will be shining to the upper left of Mars, just under 12 degrees away. On each of these nights the part of the Moon's face not lit by direct sunlight should be glowing with the subtle lavender-pink light of Earthshine, making this conjunction between the Moon and the Red Planet a tempting target for astrophotographers.

At the end of our observing period Mars will have crossed the border between Gemini and Cancer, and will be close to the much-loved star cluster Messier 44, the Beehive Cluster. But by then it will be low in the twilight sky, and you'll need a flat horizon with no trees or buildings blocking your view if you want to see that celestial close encounter.

Out at Mars itself, this will be a busy and exciting time. Not only will NASA's Perseverance rover be well into its mission to look for signs of ancient Martian life at its landing site in Jezero crater, but there will hopefully be another rover arriving on the Red Planet to begin studying it. May is when the Chinese rover Tianwen-1 is expected to land on Mars, although that might be delayed until June.

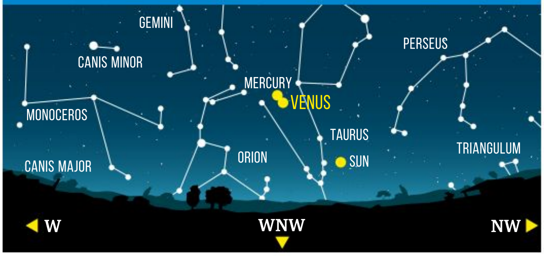
MERCURY 20:00 BST on 27 May



Constellation: Taurus **Magnitude:** +0.9 **AM/PM:** PM

Mercury will be an evening object during our observing period, becoming visible as a copper-hued ‘star’ low in the northwest as the sky begins to darken after sunset. On 20 May it will be shining to the upper left of much brighter and more obvious Venus, and will be setting around two hours after sunset, giving you a good stretch of time to look for it.

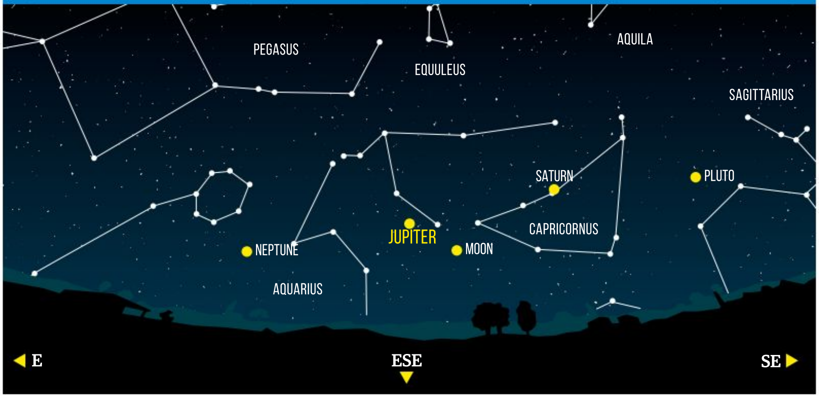
VENUS 20:00 BST on 27 May



Constellation: Taurus **Magnitude:** -3.9 **AM/PM:** PM

Venus will be easily visible to the naked eye as a bright, silvery star low in the northwest soon after sunset, setting more than an hour after the Sun. In late May Venus will be joined by Mercury, and the two will appear close together in the twilight for a few days, at their closest on 28 May, when they will lie just a Moon’s width apart.

JUPITER 03:00 BST on 1 June



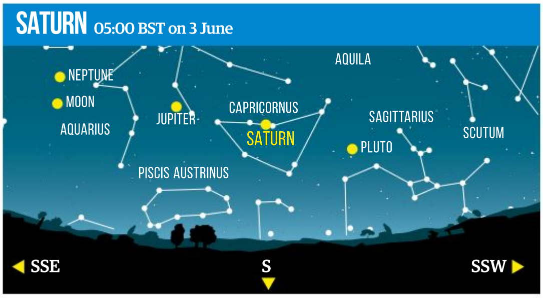
Constellation: Aquarius

Magnitude: -2.3

AM/PM: AM

Jupiter, the largest planet in the Solar System, is a morning object during the coming month. Shining at magnitude -2.3, it will be an easy naked-eye object, even with the morning’s creeping light. You’ll find it shining low in the southeast before sunrise, 17 degrees to the lower left of fainter Saturn, which it will remain close to throughout the summer. Jupiter’s visibility will steadily improve as each morning passes, and by the middle of June it will be rising three hours before the Sun, although it will remain low in the sky until dawn washes it from view.

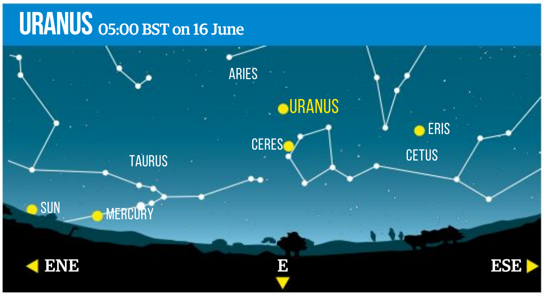
SATURN 05:00 BST on 3 June



Constellation: Capricornus **Magnitude:** +0.6 **AM/PM:** AM

The famous Ringed Planet will be visible as a yellow-white star before sunrise, shining low in the southeast and to the right of much brighter Jupiter. At the start of our observing period Saturn will be rising two hours before the Sun, and by the middle of June will be rising almost four hours before it, making this a good observing period for Saturn-watchers.

URANUS 05:00 BST on 16 June



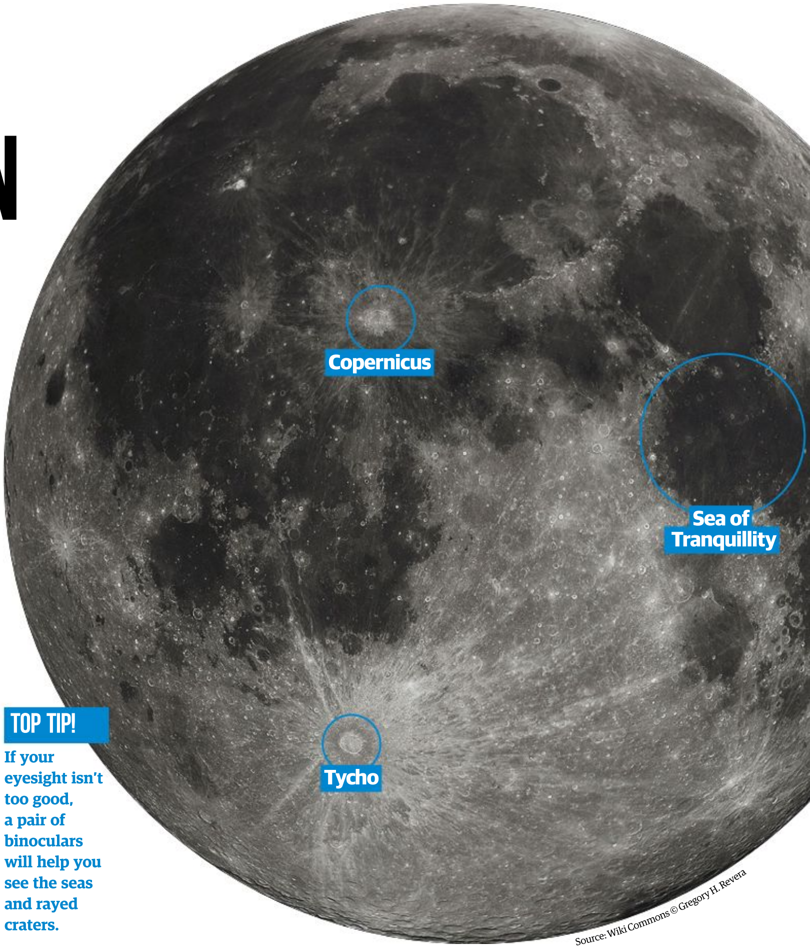
Constellation: Aries **Magnitude:** +5.9 **AM/PM:** AM

Uranus will be hard to see. Although its magnitude of +5.9 means it qualifies as a naked-eye object, that only really relates to a dark sky. This month Uranus will be fighting against the brightening morning light, so you’ll probably need binoculars to pick it out from the equally faint and unimpressive background stars of Capricornus.

MOON TOUR

FULL MOON

What can you see on this month's supermoon as it rises above the horizon?



Source: Wiki Commons © Gregory H. Revera

TOP TIP!

If your eyesight isn't too good, a pair of binoculars will help you see the seas and rayed craters.

On 26 May one of nature's most beautiful events will take place in the night sky: a total lunar eclipse. As the Moon slides into the long cone of shadow cast through space behind the Earth by the Sun, its normally silvery-white disc will darken from one side. Over several hours the darkened area will creep further and further across the disc until it completely covers it. Then the Moon will undergo a startling transformation – it will turn an orange-brown colour, like it has been dipped in rusty water. This total phase ends as the Moon emerges from Earth's shadow.

Unfortunately, this striking event won't be visible from the UK – you'll need to be in the Pacific to see it – but the full Moon on that night will still be worth looking at because it will be closer to Earth than usual and therefore larger in the sky. These lunar close encounters are now widely known as supermoons, offering beginners a great opportunity to get to know the face of our planet's satellite.

But wait – doesn't every book and magazine say that the full Moon is absolutely the worst time of the month to look at our cosmic next-door neighbour? That's true if you're an experienced lunar observer who likes zooming in on its craters, mountains and valleys, but if you just want to see the Moon's major features, a full Moon is perfect.

If you look at the full Moon with your naked eye when it is high in the sky, you might need to look away again because it is so brilliantly bright, just a small bone-white disc. But if you can catch the full Moon when it is lower in the sky, just after it has risen or before it sets, you'll be able to see features on its face because there will be less contrast between it and the black sky around it.

The first thing that you'll notice is that the Moon's face is split into strikingly different areas of light and dark. The lighter areas are called the lunar highlands by astronomers. They are regions of very rough terrain, formed from countless thousands of holes, or craters. In some places the craters are packed so close together they overlap. Some lunar craters are hundreds of kilometres across, while others are much smaller pits only a few kilometres wide. All the large craters and many of the smaller ones have names honouring astronomers and other famous scientists and explorers.

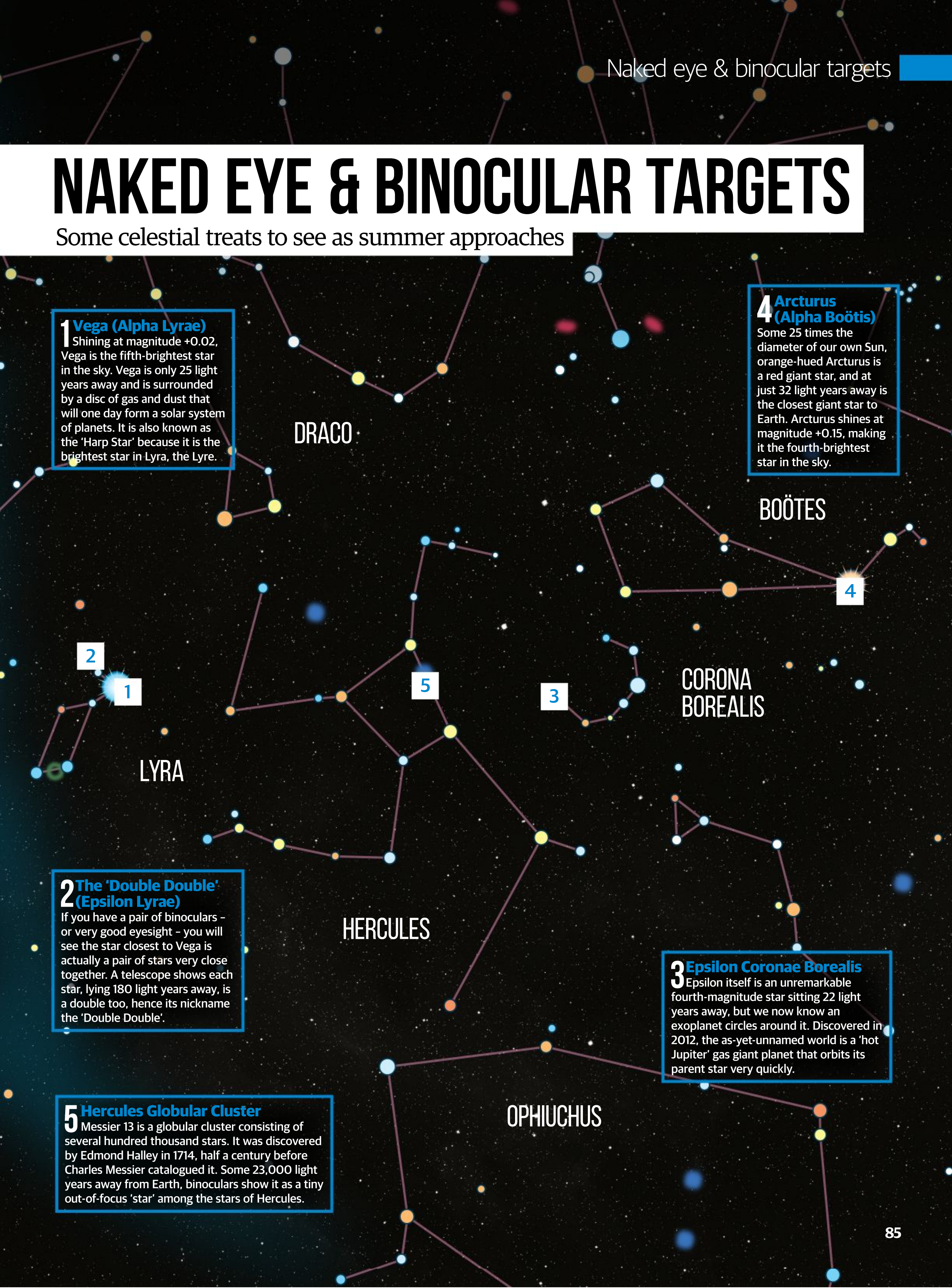
The darker areas are the famous lunar seas, or maria. But these are not oceans of water – the maria are areas covered over by molten lava which flowed across the Moon many billions of years ago after huge meteorite impacts. They are much flatter than the highlands, but are also spattered with craters. The seas all have names, and even if you've never taken a proper look at the Moon before you'll know one of them – Mare Tranquillitatis, the Sea of Tranquillity, where Neil Armstrong took his famous 'one small step for man' in 1969 on the Apollo 11 mission. Other seas have romantic and evocative names such as the Sea of Serenity and the Sea of Nectar, which sound much nicer places for future astronauts to visit than the Sea of Decay...

If your eyesight is good, you'll be able to make out bright lines radiating away from some of the craters. These are 'rays', trails of rock and dust that sprayed away from meteorite impacts and fell down onto the Moon's surface. Craters surrounded by rays are young – in astronomical terms, at least. We can tell they were formed after the huge lava floods that created the seas because they are splattered across them and cover up the lava plains beneath them.

On the night of the 26 May supermoon, two craters surrounded by rays will stand out particularly clearly. Down near the bottom of the Moon you'll see Tycho, which is the source of some of the longest and most prominent rays on the whole of the Moon. To its upper left, near the centre of the lunar disc, you'll see Copernicus, the 'Monarch of the Moon', almost 100 kilometres (62 miles) across and surrounded by such an impressive system of rays that it looks like a huge can of paint has dropped onto the Moon.

NAKED EYE & BINOCULAR TARGETS

Some celestial treats to see as summer approaches



1 Vega (Alpha Lyrae)

Shining at magnitude +0.02, Vega is the fifth-brightest star in the sky. Vega is only 25 light years away and is surrounded by a disc of gas and dust that will one day form a solar system of planets. It is also known as the 'Harp Star' because it is the brightest star in Lyra, the Lyre.

2 The 'Double Double' (Epsilon Lyrae)

If you have a pair of binoculars – or very good eyesight – you will see the star closest to Vega is actually a pair of stars very close together. A telescope shows each star, lying 180 light years away, is a double too, hence its nickname the 'Double Double'.

3 Epsilon Coronae Borealis

Epsilon itself is an unremarkable fourth-magnitude star sitting 22 light years away, but we now know an exoplanet circles around it. Discovered in 2012, the as-yet-unnamed world is a 'hot Jupiter' gas giant planet that orbits its parent star very quickly.

4 Arcturus (Alpha Boötis)

Some 25 times the diameter of our own Sun, orange-hued Arcturus is a red giant star, and at just 32 light years away is the closest giant star to Earth. Arcturus shines at magnitude +0.15, making it the fourth-brightest star in the sky.

5 Hercules Globular Cluster

Messier 13 is a globular cluster consisting of several hundred thousand stars. It was discovered by Edmond Halley in 1714, half a century before Charles Messier catalogued it. Some 23,000 light years away from Earth, binoculars show it as a tiny out-of-focus 'star' among the stars of Hercules.

Messier 56

© NASA

DEEP SKY CHALLENGE

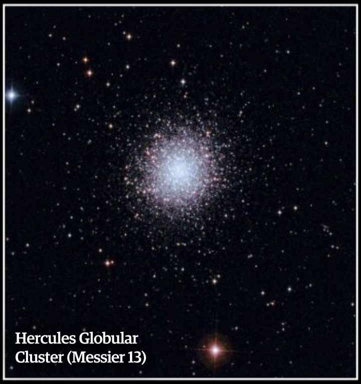
A GAGGLE OF GLITTERING GLOBULAR CLUSTERS

Messier 13 isn't the only stellar gathering to see in the early summer sky

As spring slides into summer, the brightness of the night sky makes observing deep-sky objects quite a challenge. The misty nebulae and smoky galaxies that fill our eyepieces on the long, frosty nights of darker seasons become washed out by the lingering twilight. Fortunately, there are plenty of other deep-sky objects to track down and observe, like globular clusters.

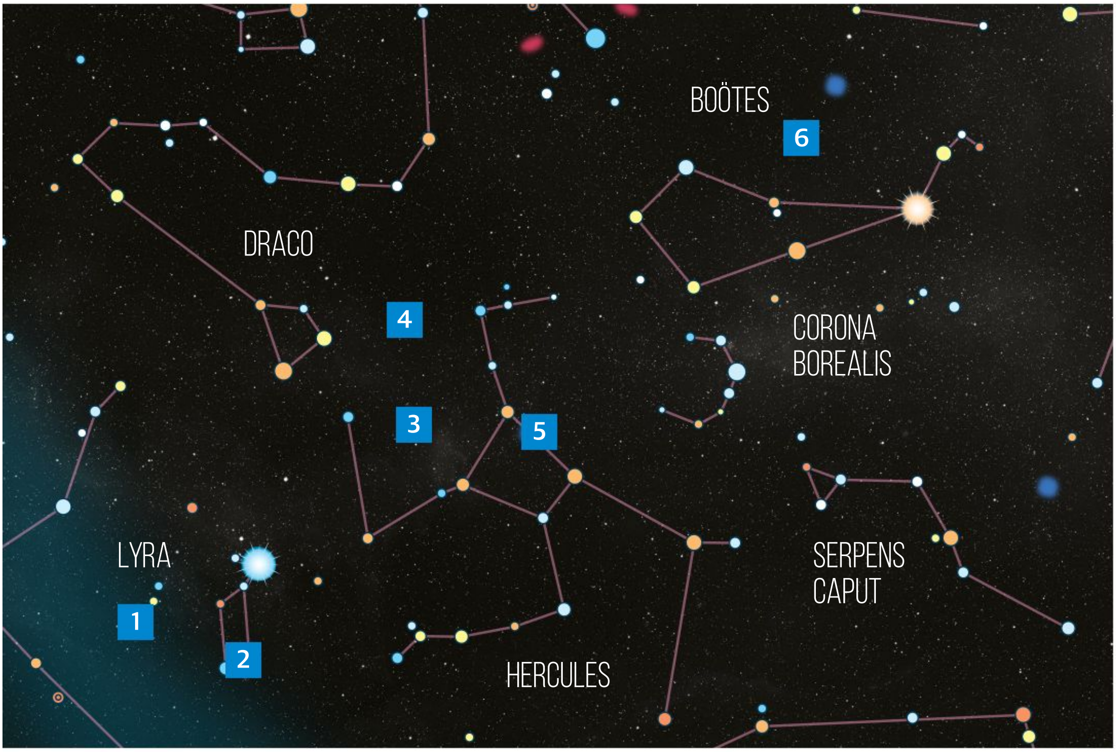
Globular clusters are enormous, spherical groups of tens or even hundreds of thousands of stars, but because they are so far away they only appear as small, round smudges in our telescopes. The most famous globular in the northern sky is Messier 13, the Hercules Globular Cluster. It's surrounded by many others that are well worth an observer's attention on a clear night at this time of year, but suffer from being in its shadow - if the beautiful Messier 92 was in another part of the sky it would be much more popular, but with Messier 13 just a short star hop away, it is overlooked.

Also visible at this time of year is Messier 57, the Ring Nebula. Although it's brighter than many of the other objects on this month's list, your challenge is to detect its subtle pastel colours and the faint star at its centre.



Hercules Globular Cluster (Messier 13)

© Getty



1 Messier 56

This fine, eighth-magnitude globular cluster is roughly spherical. In a high-power eyepiece you'll see an attractive mix of faint blue and red stars, with a triangle of brighter stars embedded in its western edge.

3 Messier 92

This sixth-magnitude globular cluster is a very rich, condensed ball of blue-white stars. Almost perfectly symmetrical, it is a beautiful sight in any telescope, but is sadly overshadowed by the much larger and brighter Messier 13 nearby.

5 Hercules Globular Cluster (Messier 13)

The finest cluster in the northern sky, Messier 13 is a spectacular sight in a large telescope: a beautiful ball of glittering blue-white stars with cobweb strands of fainter stars spraying away from its outer edges.

2 The Ring Nebula (Messier 57)

The most popular planetary nebula in the northern sky, you'll need to be under a very dark sky and using a large telescope to see its blue and green colours and the faint star in its centre.

4 The Prize Comet Cluster (NGC 6229)

This little-known tenth-magnitude globular cluster is 99,000 light years away. High magnification is needed to reveal its condensed core of pollen-grain grey-blue stars surrounded by a cage of brighter yellow stars.

6 The Snowglobe Cluster (NGC 5466)

With no central condensation this small, tenth-magnitude object looks more like an open cluster than a globular. Looking at it under high power, you'll be reminded of a miniature version of Messier 44, the Beehive Cluster.

Messier 92

© ESA/Hubble & NASA

THE NORTHERN HEMISPHERE

Late-night astronomers are treated to a stunning selection of deep-sky objects

The short summer nights are warm, but don't leave much time for observing – still, there's plenty around to see. The constellation of Boötes rides high with Arcturus, the brightest star in the northern celestial hemisphere, and is high to the south after sunset. Look out for the brilliant star Vega in the constellation of Lyra, not far from the celebrated Ring Nebula (Messier 57), a planetary nebula that looks like a smoke ring through a small telescope. Towards the southern horizon are the constellations of Sagittarius and Scorpius, where the centre of our galaxy is located. Here the Milky Way is at its densest, with plenty of stars and star clusters for you to seek out, such as Messier 4, 6, 7 and 25.

USING THE SKY CHART

This chart is for use at 22:00 (BST) mid-month and is set for 52° latitude.

1. Hold the chart above your head with the bottom of the page in front of you.
2. Face south and notice that north on the chart is behind you.
3. The constellations on the chart should now match what you see in the sky.

MAGNITUDES

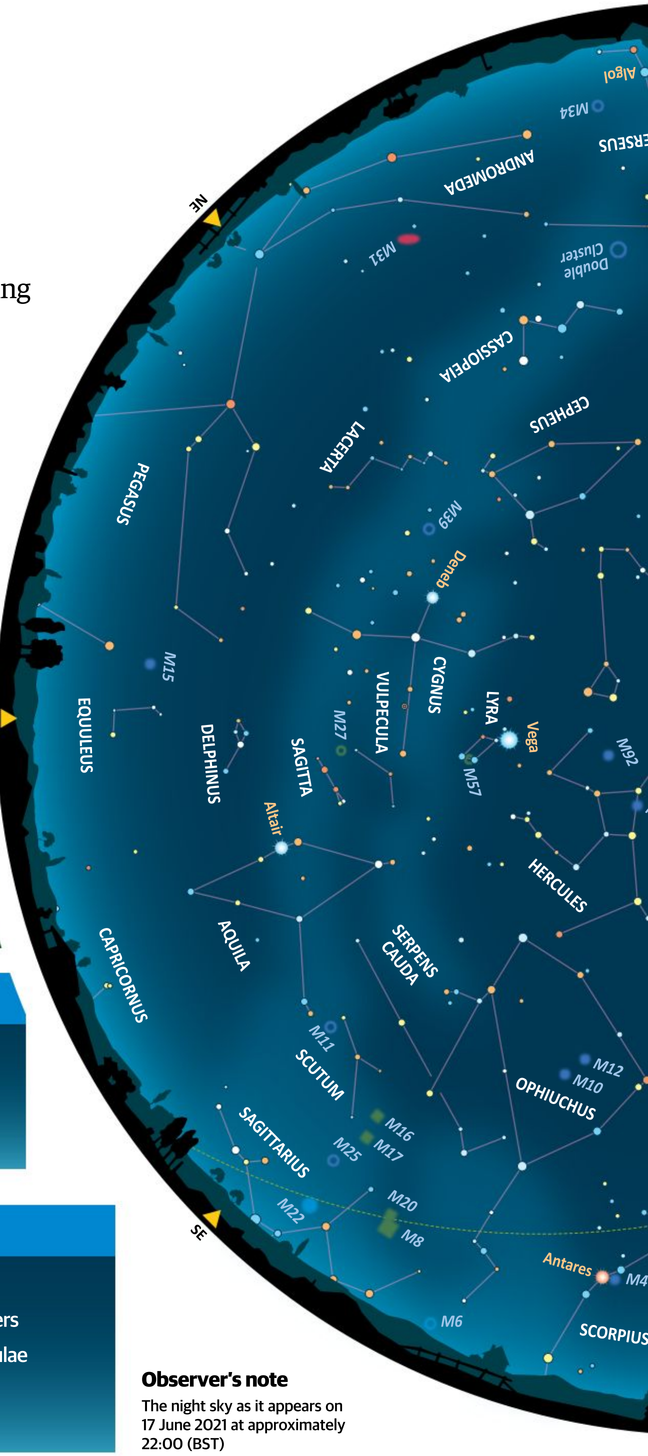
- ● Sirius (-1.4)
- ● -0.5 to 0.0
- ● 0.0 to 0.5
- ● 0.5 to 1.0
- ● 1.0 to 1.5
- ● 1.5 to 2.0
- ● 2.0 to 2.5
- ● 2.5 to 3.0
- ● 3.0 to 3.5
- ● 3.5 to 4.0
- ● 4.0 to 4.5
- ● Fainter
- ● Variable star

SPECTRAL TYPES

- ● O-B
- ● A
- ● F
- ● G
- ● K
- ● M

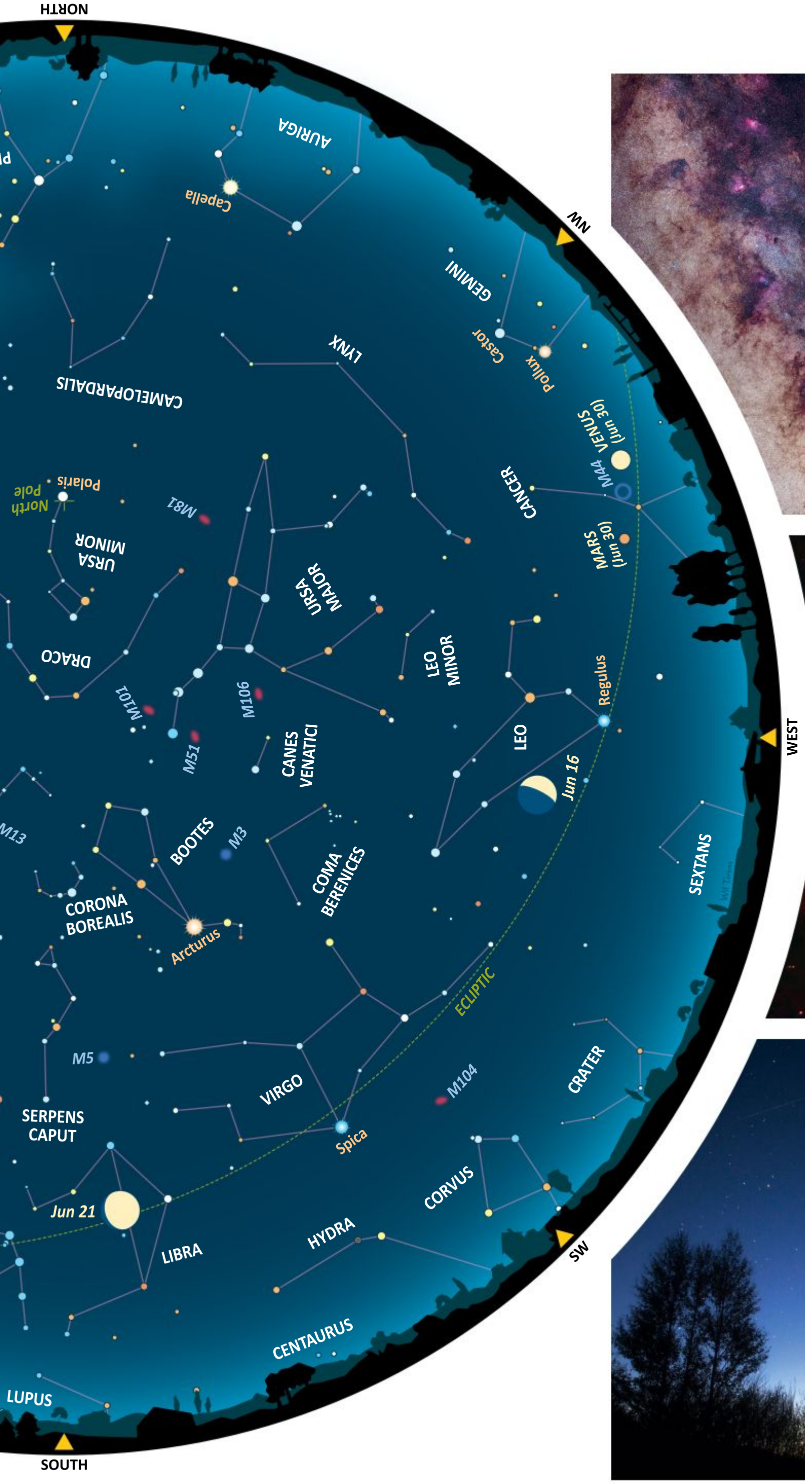
DEEP-SKY OBJECTS

- ○ Open star clusters
- ● Globular star clusters
- ■ Bright diffuse nebulae
- ○ Planetary nebulae
- ● Galaxies



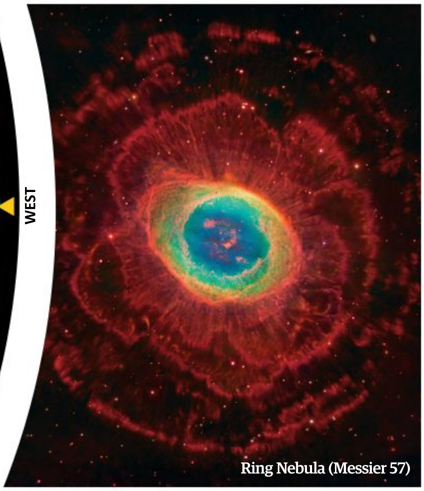
Observer's note

The night sky as it appears on 17 June 2021 at approximately 22:00 (BST)



The Milky Way around the Small Sagittarius Star Cloud (Messier 24)

© Getty



Ring Nebula (Messier 57)

© Getty

Arcturus (Alpha Boötis)

© Getty

ASTROSHOTS OF THE MONTH

Get featured in **All About Space** by sending your astrophotography images to **space@spaceanswers.com**

Above: Andromeda Galaxy (Messier 31)

Left: Messier 81 (Bode's Galaxy) and Messier 82 (Cigar Galaxy)

Right: Pleiades star cluster (Messier 45)

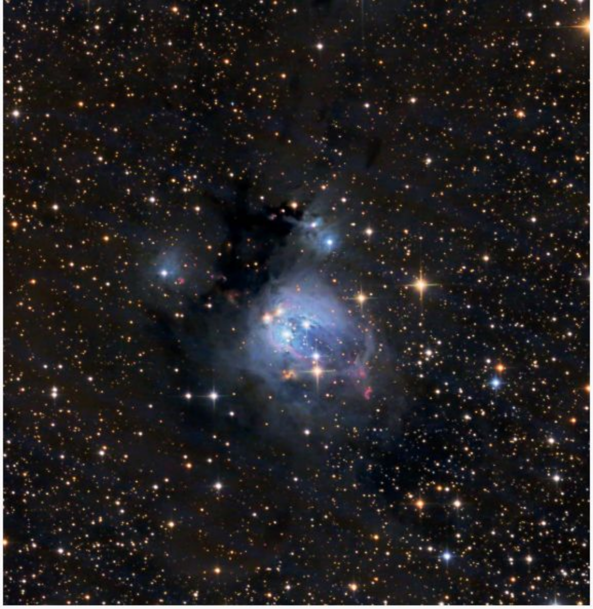
Jeff Johnson

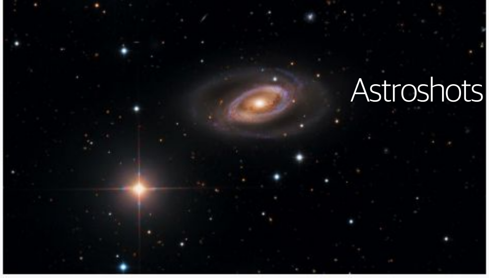
Location:
Las Cruces, New Mexico

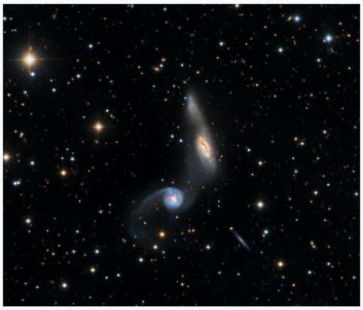
Telescope:
Takahashi FS-60C refractor

"I have a long love of astronomy, which began when I was ten years old, and I have observed the night sky for many years with binoculars and a telescope. I did my first 'real' astrophotography in 1996 when I used a 35mm SLR camera to take photographs of Comet Hyakutake. I took a tripod out into the desert here in Las Cruces and experimented with different exposures.

"Later I bought a 10" Dobsonian telescope for observing the night sky, and within a week I was taking pictures through the eyepiece for fun. Within a few more weeks, I knew I wanted to get serious with astroimaging."







Above: Spiral galaxy NGC 1350

Left: Seyfert galaxy NGC 2992

Warren Keller

Location: West Virginia

Telescope: Officina Stellare RiDK 700

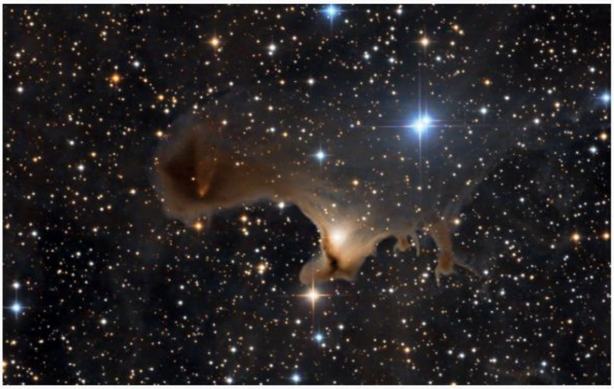
"A child of the 1960s, I boldly went with my heroes 'where no man had gone before', and I never really touched down again. I began exploring the night sky at 15 years old with an eight-inch Newtonian, and I knew from the moment I received Fred Hoyle's book, *Astronomy*, I would someday photograph the wonders of the heavens.

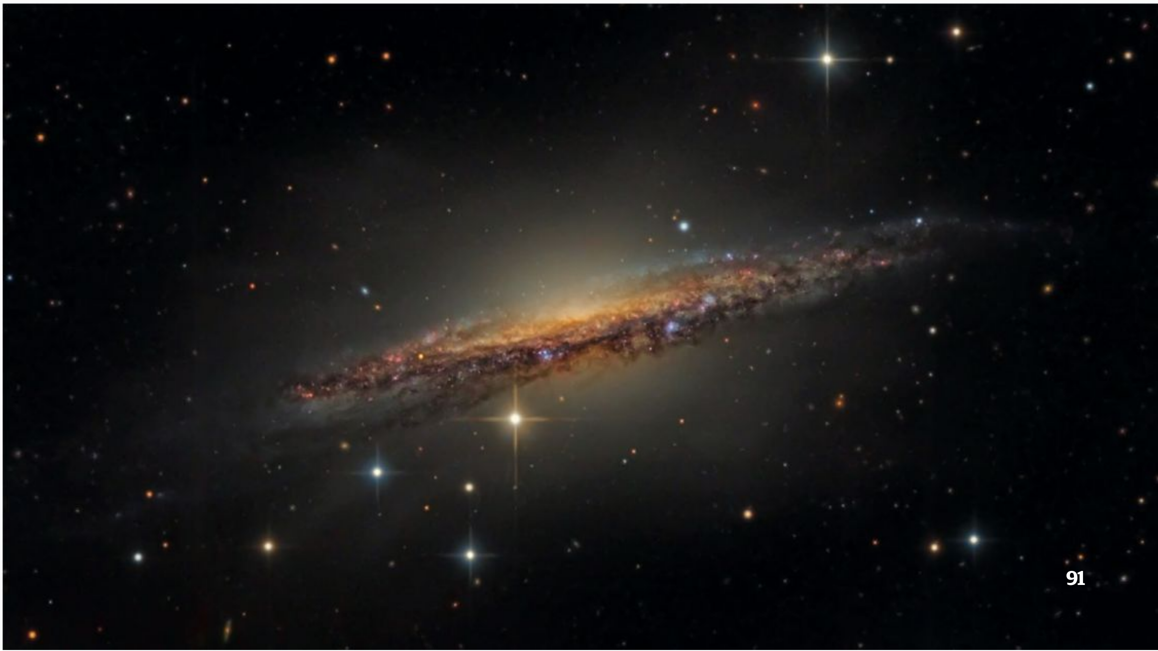
"I started out using film in 1998, and then I switched to a charge-coupled device (CCD) in 2003. I am artistic by nature, so it's less about the cosmology and more about the thrill of the hunt for the myriad of beautiful shapes and colours throughout the universe."

Above: Reflection nebula NGC 7129

Right: Ghost Nebula (Sh2-136, VdB 141)

Below: Edge-on spiral galaxy NGC 1055





REVIEW

CELESTRON CPC 800 GPS (XLT)

With its StarBright XLT technology, this catadioptric instrument is worth every penny: an excellent investment for serious sky-watchers

Reviewed by Gemma Lavender

TELESCOPE ADVICE

Cost: £2,249 (approx. $3,100)

From: Wex Photo Video

Type: Schmidt-Cassegrain

Aperture: 8"

Focal length: 80"

BEST FOR...

- ? INTERMEDIATE
- £ HIGH BUDGETS
- ◉ PLANETARY VIEWING
- ☽ LUNAR VIEWING
- ● DEEP-SKY OBJECTS

With the Celestron CPC 800 GPS, you certainly get what you pay for. An incredibly well-made instrument, this beautifully presented and robust telescope is ideal for those looking to upgrade with an all-rounder that also allows for some serious astrophotography.

The CPC 800 GPS is supplied with essential accessories, including a 9x50 optical finderscope with quick-release bracket, a handset for navigation, an accessory tray, a 40mm high-quality eyepiece and a 1.25-inch star diagonal. Celestron's Starry Night Special Edition software is also included.

Being a highly revolutionary instrument, the telescope features its own internal Global Positioning System (GPS) that automatically works out the date, time, longitude and latitude of your observing location without any input from the user. Alignment of the telescope is achieved at the press of a button using Celestron's SkyAlign technology, making setting up easy.

The Celestron CPC 800 GPS may look daunting to build, but Celestron has provided in-depth instructions for fuss-free construction, leaving any sky-watcher fully guided through the process.

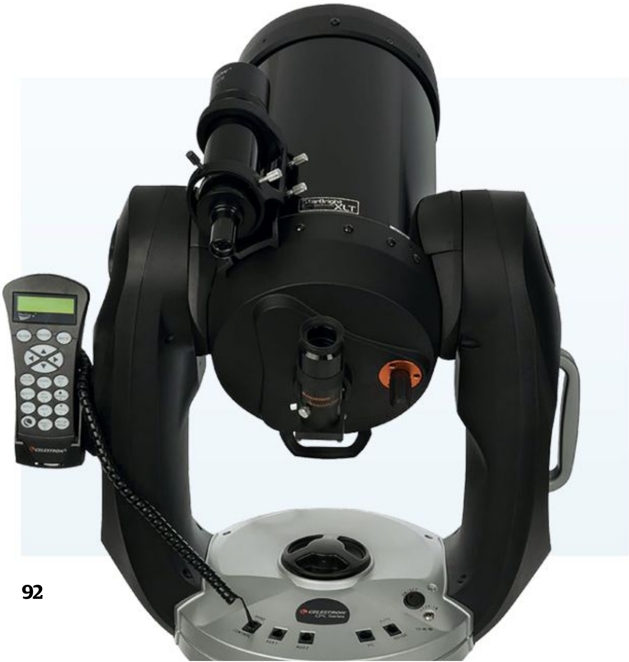
On setting up the telescope, it's hard not to note the superb quality of the tube, tripod and mount, fashioned from long-lasting aluminium, steel and thick plastic. Peering into the objective lens, a coating of StarBright XLT is evenly spread across the full eight inches. The telescope will take more than a few minutes to set up, compared to our quick experiences with the Celestron NexStar 6SE and Astro Fi 130, but this is to be expected - especially if you have never put a computerised instrument together before. However, we do think that the general set-up process is intuitive thanks to the excellent design and supplied Celestron support.

With the massive amount of rain we experienced throughout January, we waited quite some time for a sufficiently clear night to test the CPC 800 GPS' mettle on a variety of targets. We were rewarded for our patience, and were eventually able to position the telescope under a clear, dark sky towards the end of the month.

As expected - and since it's comprised partly of steel - the CPC 800 GPS is very heavy, weighing in at 27.6 kilograms. While the fork mount makes lifting the telescope a touch easier compared to its single-arm cousins, we recommend getting someone to help you carry it to your chosen observing site or transporting it in a vehicle. For just transporting the tube, a handy carry handle has been built in. While it's quite easy to view the heftiness as a negative, many sky-watchers will be thankful for such a robust build: even with a prevalent icy breeze, the telescope stands impressively still. A CCD camera was also attached, with the CPC 800 GPS supporting the additional weight well.

The Celestron CPC 800 GPS operates on nine slewing speeds, with the fastest speed being five degrees per second. Tracking rates are in sidereal, solar and lunar, and the supplied NexStar database features over 40,000 objects.

With the constellations of Ursa Major (the Great Bear), Leo (the Lion), Virgo (the Virgin) and Ursa Minor (the Little Bear) shining in the sky, we were excited to view their many deep-sky treasures using



Main: The telescope and tripod both have a robust build for steady observations

Right: A 9x50 optical finderscope is included in the package

Left: Both aligning the telescope and finding objects to observe are made so simple

> “THE COMPUTERISED MOUNT OPERATES FLAWLESSLY AND IS INCREDIBLY EASY TO USE”

the eight-inch aperture of the CPC 800 GPS. However, before we could get to touring the night sky, we needed to align the telescope with the SkyAlign technology. We couldn't have been more impressed with this fantastic feature. Simply pick three bright objects in the sky - these can be the Moon, planets or low-magnitude stars - and the CPC 800 GPS' computer system does the rest of the work for you.

We took the opportunity to test how quickly the telescope's GPS was able to work out our location on a variety of observing trips beyond the backyard. We can confirm that this is a reliable feature of the CPC 800 GPS, with it taking no more than a few minutes for the system to compute our position. Users should also bear in mind that the telescope will need to be set to daylight saving time at appropriate times of the year.

The computerised mount operates flawlessly and is incredibly easy to use. Pressing the NexStar handset, we instructed the CPC 800 GPS to slew to Bode's Galaxy (Messier 81) in the constellation of Ursa Major, noting that the telescope's DC servo motors are impressively quiet. There also wasn't too much shaking of the tripod as the fork mount turned the optical tube towards the spiral galaxy.

Plugging the supplied 40mm eyepiece into the finder, we received an impressively clear view of Messier 81, with the CPC 800 GPS revealing a moderately sized bright oval. The galaxy's stunning spiral arms and fine details got better and better the more we experimented with our selection of eyepieces and filters.

Bringing our target into clear view, the focus knob doesn't operate as smoothly as we would've liked, but does the job nonetheless. Meanwhile, the star diagonal is well-orientated, allowing for comfortable views for long periods of time.

We waited until the early hours of the morning for the Pinwheel Galaxy (Messier 101) to become visible above the horizon. We were very impressed with the sight of this stunning face-on spiral, where views of the knots of star formation and the galaxy's central bulge were improved with the help of a deep-sky filter.

It wouldn't be a proper observing session without locating members of our Solar System, and Jupiter was a stunning sight at magnitude -1.7 through the Celestron CPC 800 GPS during the small hours of the morning. Using the 40mm eyepiece, the gas giant appeared as a small but crystal-clear disc, with its Galilean moons – Io, Europa, Ganymede and Callisto – showing up as points of light either side of its limbs. Allowing our eyes to adjust to the view of the planetary king, we could make out its atmospheric belts and bands clearly, while some of the gas planet's cream-coloured zones shone a bright white. No colour fringing could be seen through the telescope's optical system.

We waited until the following evening to catch Mars, which at the time could be found low in the southeast and in the constellation of Ophiuchus (the Serpent Bearer). The Red Planet was glowing at magnitude +1.6.

Locating the planet with the CPC 800 GPS' database was nothing short of a breeze, and within seconds it appeared at the centre of our field of view as an orange disc. Valles Marineris, the canyon system that stretches across Mars' equator, could be seen as a dark 'shadow'. This is an impressive sight for all levels of sky-watcher, whether you're a beginner or more seasoned observer.

While the CPC 800 GPS is considered to be an expensive piece of kit, we have to say that given the instrument's build, operation and the revolutionary technology offered, it is worth every penny.

It's built to last, offers a reliable computerised mount and is a great investment for those hunting for an upgrade. The CPC 800 GPS is an all-rounder for visual observing and astrophotography. The only minor downsides are the telescope's weight and a slightly stiff focuser.

Views of both the Solar System and deep-sky objects are exceedingly sharp and clear, with the optical system displaying no signs of distortion. As with all telescopes, we recommend furnishing the CPC 800 GPS with further accessories to get the very best out of it – views become even more pleasing the more sky-watchers experiment with magnifications and filters.

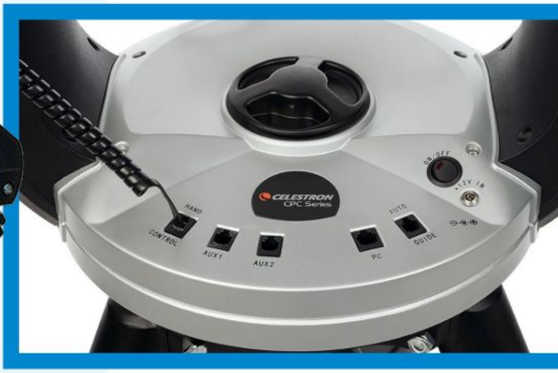
FOR

- Simple to set up
- Superb multi-coated optics
- High-definition observations
- Silent motors with minimal shaking
- Easy alignment process

AGAINST

- Very heavy, so lacks portability
- Slightly stiff focuser

Right: Although the set-up looks complex, it's very easy to use, and detailed instructions are included



Below: Controls are simple, with a variety of connections for external devices

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HISTORY OF NASA

On 29 July 1958 President Eisenhower signed into US law a federal statute that would change the universe. The National Aeronautics and Space Act led to the creation of a civilian space agency: one not controlled by generals, intelligence officials or businessmen, but by scientists. Its aim was not war, but peace. In the almost 63 years since its inception NASA has been responsible for some of the most important advances ever made. It left footprints on our Moon and sent spacecraft beyond the limits of our Solar System. Its Mars rovers search for life on the plains of the Red Planet, while Hubble looks back through time and space towards the beginning of the universe.

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The Battle of Waterloo, Martin Luther King Jr's famous speech, 9/11 – there are some events in history that truly stand out as turning points. These changed politics, civil rights, countries and continents. They are the events that shaped our world. We explore these in detail here, from the inauguration of the first president George Washington in 1789 to the first atomic bomb dropped on Hiroshima in 1945, causing unfathomable devastation. Discover the events that led to World War I, the collapse of the Berlin Wall in 1989, the fight for women's suffrage and the presidency of Abraham Lincoln, plus the lasting legacy of these iconic moments.

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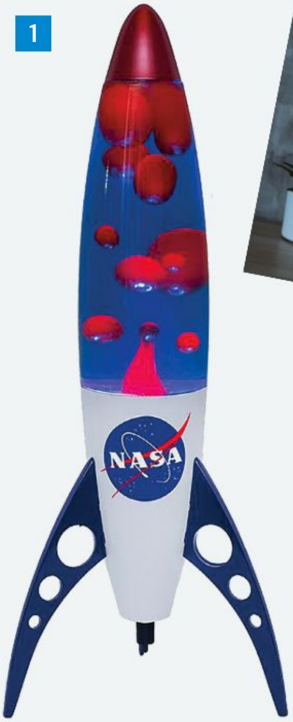

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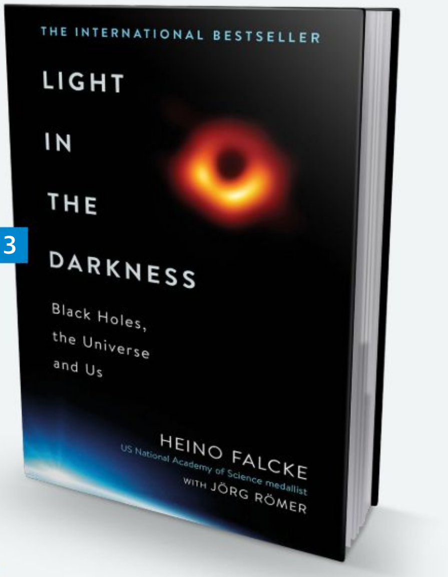

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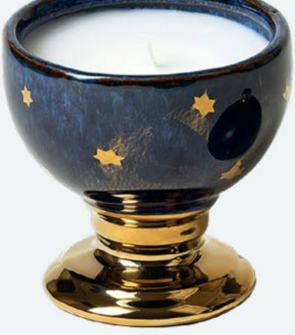

FOR YOUR DESK

NASA RETRO GALAXY LAMP

Cost: £34.99 (approx. $48.60)

From: thumbsup.com

1 Add some nostalgic flair to your home or office space with this NASA Retro Galaxy Lamp. This impressive rocket stands 50 centimetres (19.7 inches) tall and is the perfect gift for the space – or lava lamp – enthusiast in your life. The lamp requires an R50 E14 40W bulb, which is included, and is powered by UK mains. Simply unbox, assemble, turn on and wait for the mesmerising wax shapes to appear. This NASA lamp effortlessly creates a chilled-out atmosphere with a stellar glow, ideal for both parties or quiet nights in.

FOR YOUR HOME

GLOBE VIOLET & ROSE BLUE CERAMIC SCENTED CANDLE

Cost: £19.50 (approx. $27.00)

From: Oliver Bonas

2 This elegantly decorated ceramic-lidded candle with a floral, woody aroma makes for the perfect addition to your home. Measuring 12.5 by 8 centimetres (4.9 by 3.1 inches), this charming little candle is delicately embellished with a deep-navy reactive glaze and hand-painted celestial scenes. With approximately 20 hours burn time, it may be small, but it packs quite the aromatic punch. It's fragranced with notes of rich sandalwood and leather tempered by floral middle notes of violet and iris, with base notes of cedarwood and musk.

FOR READERS

LIGHT IN THE DARKNESS: BLACK HOLES, THE UNIVERSE AND US

Cost: £10.99 paperback (approx. $15.25)
£20 hardback (approx. $27.80)

From: Waterstones

3 Feed your curiosity and explore the universe from the perspective of astrophysicist Professor Heino Falcke, who helped create the first image of a black hole. This enticing book takes you on a journey from when humans first gazed up at the heavens all the way to modern-day astrophysics and beyond. Addressing big questions, this thought-provoking exploration of the universe makes for a very interesting read.

5

4

6

FOR OBSERVERS

CELESTRON SKYPORTAL WIFI MODULE FOR IOS & ANDROID

Cost: £159 (approx. $220.80)

From: firstlightoptics.com

4 Turn your smartphone or tablet into your very own planetarium and observatory with this nifty module. By plugging the WiFi module into your telescope's hand control or auxiliary port and connecting to its wireless signal with your device, it becomes a wireless hand controller for your telescope. The SkyPortal app aligns your telescope to a selected target and can inform you of the best objects to view based on your exact time and location.

FOR YOUR DESK

PERSEVERANCE 2020 MARS ROVER ILLUMINATED SCULPTURE

Cost: £119.96 (approx. $166.60)

From: bradford.co.uk

5 Celebrate the monumental triumph of the Mars rover Perseverance with this iconic handcrafted sculpture. This hand-painted replica features adjustable accessories, including the extendable metal robotic arm and a fully rotating replica camera mount. This little sculpture is guaranteed to make a big statement, with built-in LED lights illuminating the rover's undercarriage and wheels. The base is adorned with full-colour images of Mars as well as the NASA logo and the launch date.

FOR FUN

ASTRONAUT RUBBER DUCK

Cost: £6 (approx. $8.30)

From: Science Museum

6 This little rubber duck may not be fully equipped for spaceflight, but it sure takes bath time to a whole new level. Let your imagination run wild and embark on a galactic trip from your bathtub to infinity and beyond. This little astronaut duck makes for a fun and quirky gift for space-loving kids and adults alike.

> "THIS LITTLE SCULPTURE IS GUARANTEED TO MAKE A BIG STATEMENT"

HEROES OF SPACE

DR WANDA L. DÍAZ-MERCED

After losing her sight, she became an advocate for the sonification of astrophysical data

Díaz-Merced believes that science is for everyone

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Born and raised in Gurabo, Puerto Rico, Díaz-Merced grew up playing with her sister, where they would pretend to fly their spacecraft to distant galaxies. At school she had an avid interest in science, and after winning second prize at a science fair she gained the confidence to believe that a career as a scientist was possible. To fulfil her dream, she enrolled at the University of Puerto Rico to study physics.

It was during her time at university that Díaz-Merced's path to become a scientist would take a rather different route; the sight loss she had begun experiencing during her adolescence rapidly advanced, leaving her blind.

Determined not to be beaten, Díaz-Merced persevered with her studies, repeated classes and overcame a myriad of obstacles. However, a career as a scientist began to look out of reach as Díaz-Merced struggled to access the same quality of education as her able-visioned classmates. One day a friend played Díaz-Merced an audio recording created from data from a solar flare. This ignited something inside Díaz-Merced, who soon realised that visual interpretation of data was not the only way.

Data can be translated into sound in a process known as sonification, whereby pitch, volume or rhythm can be used to distinguish between data values. Díaz-Merced soon began to investigate how our ears could detect patterns in data that could otherwise be obscured by graphs and visual representations. But Díaz-Merced was not the first to realise the benefits of sonification. Radio astronomer Karl Jansky used it to listen to the cosmos in the 1930s, but as visual data interpretation techniques advanced, sonification somewhat fell by the wayside.

Fuelled by a passion for the sonification of astrophysical data and making it more accessible to everyone, Díaz-Merced applied for an internship with heliophysicist Robert Candey at NASA's Goddard Space Flight Center in Maryland while she was still studying for her bachelor's. During the internship, Díaz-Merced was involved in developing a prototype data analysis tool that would help to acquaint the visually impaired with space-physics data. The software would convert astronomical data into sound and allow for audible interpretation of data. The internship was a great success. She then returned to her studies, and after six years of hard work she completed her bachelor's degree in physics.

Díaz-Merced continued to be involved in astrophysical research at Goddard while she completed a PhD in computer science at the University of Glasgow, Scotland. During her PhD, Díaz-Merced took sonification to a whole new level. She set out on a mission to test whether the software she had been working on at NASA would prove useful to the general science community. To test this, Díaz-Merced presented scientists with simulated data of astronomical spectra and asked them to look for the telltale double peak that stipulates the presence of a black hole. She had users try to identify signals from visual-only data, sound-only data and then a combination of the two. The experiment was a resounding success, showing that when you combine both audio and visual information your sensitivity to a signal is heightened. Díaz-Merced proved that the sonification of data is not only beneficial to those that are visually impaired, but to everyone.

Díaz-Merced has since travelled the world promoting sonification of astrophysical data and is a leading advocate for ensuring access to astronomy is available to all. "I think that science is for everyone. It belongs to the people, and it has to be available to everyone because we are all natural explorers," she said to an audience during her TED Talk in 2016.

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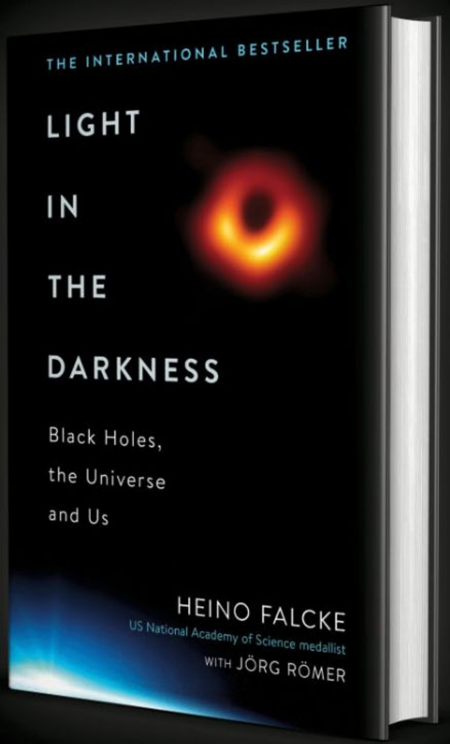

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